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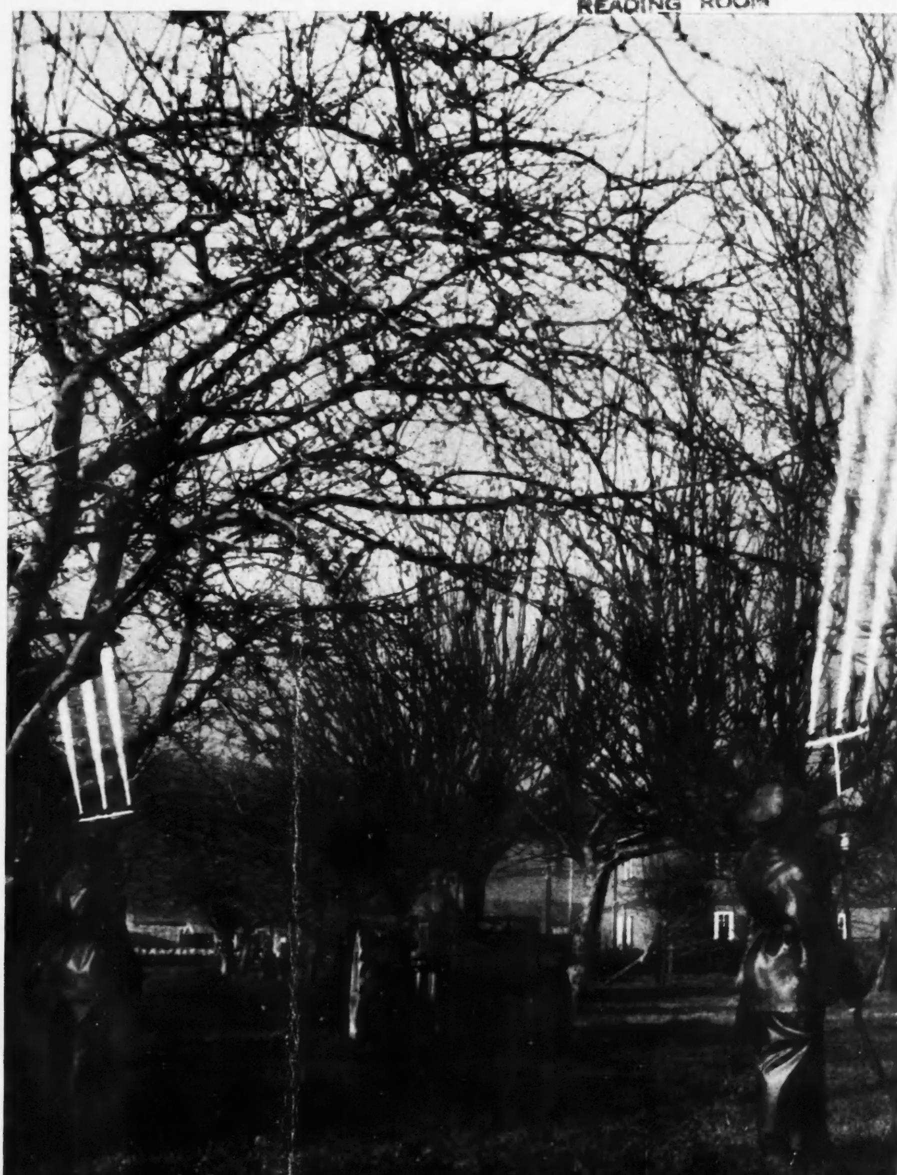

High-pressure spray lances in action in Long Ashton's cider orchard

Discovery

THE MAGAZINE OF SCIENTIFIC PROGRESS

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All subscriptions, distribution and business communications to Jarrold & Sons Ltd, Norwich *Telephone* Norwich 25261
Subscription Rates Inland and Overseas 6 months 9s, 12 months 18s *U.S.A.* 6 months $1.50, 12 months $3
Advertisement Office Aldridge Press Ltd, 15 Charterhouse Street, EC1 *Telephone* Holborn 8655

MAY 1953 VOLUME XIV NUMBER 5

THE PROGRESS OF SCIENCE

FIFTY YEARS OF FRUIT RESEARCH

Today we take for granted the winter washing of fruit trees, indispensable though this procedure is in the programme of spraying for both orchards and gardens. For this purpose tar oil wash continues to be far the most popular spray, and its versatility is impressive: take a particular type of fruit, such as apple, and it gives effective control of many insect pests, and in addition it can be applied to all kinds of fruit, both tree and soft fruits, with the exception of strawberries. The introduction of this particular wash is but one example of the big range of valuable practical results that have flowed from the Long Ashton Research Station, which celebrates its jubilee this summer.

Long Ashton's career started in 1903. It was established as the research station of a body called the National Fruit and Cider Institute, which was sponsored by the famous Bath and West Society, a group of private farmers interested in cider, and six county councils. The station's first activities were all concerned with cider. Experiments designed to solve problems connected with cider-making were started in a small farm building, to which was attached a lean-to shack, which was the only laboratory accommodation available to B. T. P. Barker—a young Cambridge graduate who was put in charge of the station and who was, to begin with, the only scientific member on its staff! Problems arising in the management of cider orchards were investigated on the eight acres of adjoining land.

The whole of Dr. Barker's career was bound up with Long Ashton, and he was able to direct its growth from that very small nucleus right up until 1943, when he retired.

Just before the First World War, Long Ashton's status changed, and it became an Agricultural Research Institute associated with Bristol University. Its programme of research was now widened to cover "Problems of Fruit Culture and the Practical Control of Diseases and Pests of Fruit Trees", as well as scientific problems of the cider industry, and this was followed by a considerable expansion of the station. The experimental farm grew to over a hundred acres, and a new laboratory building was erected.

Already the station had obtained results of practical benefit to the local cider industry. Now its research activities along a much wider front began to yield significant results, and its findings came to affect the practice of fruit growing all over Britain.

It was Long Ashton's mycologist, S. P. Wiltshire, who in 1921 introduced the tar oil technique for winter spraying from Holland. This was perfected by Long Ashton scientists, in particular A. H. Lees, and was rapidly adopted by practical farmers.

Soon afterwards Long Ashton discovered the cause of 'reversion' in blackcurrants. This pernicious disease, which ruins the fruit crop, is characterised by the radical change in the shape of the leaves. Practically nothing could be done about it until the Long Ashton workers succeeded in proving that this disease is due to a virus and that the virus is carried by the mite which causes 'big bud'. The next step was to work out a method for killing the mite, and so originated the familiar procedure of spraying the bushes with 2% lime sulphur when the leaves are the size of a florin. This is effective because it hits the mites just when they are migrating on the young leaves, and are thus most vulnerable to an insecticidal spray.

The nutrition of fruit trees has been under continuous study, from which many important facts have emerged. In particular Long Ashton did pioneer work which brought home the supreme importance of potash in fruit growing.

Its investigations into deficiency diseases caused by the lack of such elements as magnesium, iron and manganese, and which commonly occur in orchards, have also helped farmers enormously. Here is a good example of the type of defect which can now be corrected in practice at a relatively low cost, though before a long series of carefully planned experiments had been carried out these deficiencies could not even be diagnosed with any degree of certainty. The present director, Prof. Tom Wallace, takes a particular interest in this line of work, and his colour atlas* is as

* *Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms—A Colour Atlas and Guide* (published by H.M. Stationery Office).

useful in the practical diagnosis of such diseases as are the illustrations to Bentham and Hooker's *Flora* to the field botanist.

The station's cider work led quite logically to a study of the commercial possibilities of the juices extracted from other fruits besides apple. From this project, in which V. S. Charley was the outstanding figure, came the black-currant syrup which is marketed on a considerable scale in this country.

Readers will be familiar with the method of preserving fruit pulp that depends on the use of sulphur dioxide. This technique, which is widely used by jam makers, was developed by Long Ashton. It was also responsible for the adaptation of this method for the benefit of the housewife—the domestic modification is, of course, the very simple method of bottling fruit in which Campden tablets are used to prevent the fruit from fermenting.

Considerable effort has been put into the breeding of new varieties of fruits. This started in the 1920s and several new varieties of apples, plums and pears resulting from this breeding programme have recently become available.* Two blackcurrant varieties, Mendip Cross and Cotswold Cross, are now well known, and a third, Malvern Cross, is coming into commercial favour.

It is quite impossible to do justice to the achievements of Long Ashton over a period of fifty years in a short note, and here we have only attempted to indicate the practical importance of the results obtained there. Discoveries of great academic interest in such fields as plant physiology have had to be ignored. Readers who want to find more information about the station should consult the series of Annual Reports issued by Long Ashton, and the references which these contain make it possible to trace every research paper published by its scientific staff.

* These include the plums called Severn Cross and Wye Cross; and two dessert pears, Bristol Cross and Cheltenham Cross.

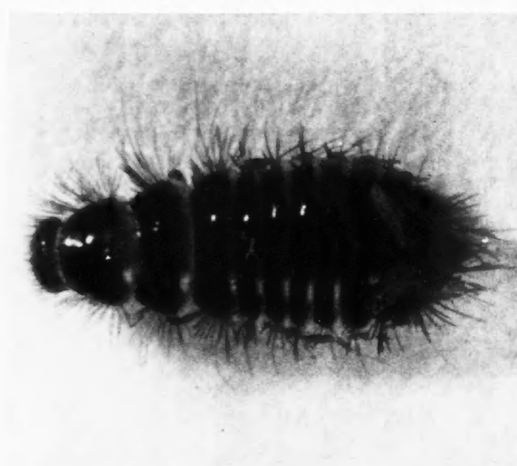
THE 'WOOLLY BEAR': A PEST ON THE MARCH

A household pest which often does a great deal of damage before its presence is noticed is the 'woolly bear', which is the grub of the carpet beetle. The Pest Infestation Laboratory of the D.S.I.R. is concerned by the fact that it is spreading, particularly in southern England, and has set up a special team to study it.

The laboratory also wants to find out the extent of damage done by the 'woolly bear' in commercial premises, which it suspects may be substantial in textile areas of the north, and is inviting manufacturers to co-operate by notifying outbreaks of the pest.

It is the grubs which do the damage, not the adult beetles. The photographs show typical specimens of both stages. The adults look something like small greyish or brownish ladybirds, though their elytra lack the gloss of the ladybirds; their size is one-sixteenth to one-eighth of an inch long. In spring and early summer they are to be found out of doors on certain flowers (especially the hogweed), and are often seen on window ledges and walls at those times of year. (Occasionally the adults are to be observed at other times in heated premises.) These beetles are, of course, responsible for spreading infestation, and they are good flyers. They insert their eggs firmly into materials which form suitable foodstuffs for the grubs.

The house with birds' nests in the eaves is the most vulnerable to the pest, because it offers a perfect route of entry. The grubs are nearly always found in nests. When they hatch out, they crawl through into the attic and start to feed on the material there. Usually there is plenty of this. Lagging materials round pipes or tanks, blankets and curtains and so on that are stored there provide food. The grubs eat almost anything of animal origin. They will chew holes in clothing, carpets, furs, hides, leather, feathers and many more kinds of stuff. Even cotton, which has no



The Varied Carpet Beetle (*Anthrenus verbasci*), which is rapidly becoming an important domestic pest in Britain. Its cream-coloured grubs (*right*) are known as woolly bears; when fully grown these are a quarter of an inch long, and covered with dark brown bristles. The grubs of other species are very similar. (*Photos by J. H. Hammond, A.R.P.S., of the Pest Infestation Laboratory.*)

LONG ASHTON RESEARCH STATION

(Above) *General view of the station's farm. The main laboratory building extends to the left-hand edge of the picture.* (Right) *Long Ashton has contributed much to the development of spraying equipment such as the mobile sprayer seen in action in this photograph.*

food value, will be damaged by them. From the attic the grubs spread downwards, along hot-water pipes. They like warmth, and will usually make for the airing cupboard, which is, to them, a heated food store. Here they will eat through the winter, with dire results to the contents. They can spread rapidly to all parts of the house, making it extremely difficult to get rid of them. If necessary, they can live on the fluff in spaces between floorboards or under skirtings.

But this route can be short-circuited; it would be perfectly possible for the mobile adult to lay its eggs directly on a carpet, for instance.

The grubs seem fairly resistant to the ordinary insecticides, so 'spring cleaning' appears to be the best means of controlling them. If possible, infested stuff should be burnt. If this cannot be done, it should be given a thorough brushing and vacuum cleaning on both sides. Old birds' nests should be removed from the eaves and also burnt. Any entrance holes to the roof space should be stopped up with mortar or fine wire mesh.

The conventional insecticides are effective against 'woolly bears'. Boxes, trunks and cupboards can be treated with crystals, such as naphthalene or paradichlorbenzene, which vaporise slowly. These should be replenished at intervals. Insecticides are useful as an additional safeguard. Clothes or blankets which are rarely used can be impregnated with D.D.T. during dry cleaning. Edges of carpets and underfelts should be treated in a 6-inch-wide

band round the underside with a liquid household insecticide which should contain 10 per cent D.D.T. and pyrethrum. This should also be applied on the top of carpets where heavy furniture stands. Ten per cent D.D.T. and pyrethrum in powder or spray form should also be used in floor cracks and under skirting boards. Roof spaces are probably best dealt with by a smoke generator, but there is no easy way to control the insects. A careful watch should be kept for them, particularly in late spring and autumn, and attacks dealt with straight away.

THE MECHANISM OF HEARING

There are some sense organs that are stimulated into action by mechanical distortion; into this category fall the touch corpuscles and also the ear, or rather the inner parts of the ear.

The obvious question is, how does a mere mechanical deformation set up nerve impulses, which are electrical in nature, as has been so convincingly demonstrated by Professor Adrian and others? This question has never yet been fully answered. Now, however, an American scientist, Dr. Hallowell Davis, who is Director of Research in the Central Institute for the Deaf at St. Louis, Missouri, has boldly given voice to a hypothesis about the nature of the mechanism in the ear.

It is well known that hearing results from sound waves that enter the outer ear. These are pressure waves in the air, and they make the ear-drum move backwards and forwards in synchronism with them. These movements of the drum are transferred by means of tiny articulated bones to an inner drum called the oval window. Behind this window there is a structure of extraordinary delicacy and beauty, so extremely small that in whole-ear diagrams of practicable text-book size this structure cannot be shown in any detail at all. The part of this structure responsible for hearing is the cochlea.

The structural pattern of the cochlea is that of a snail's shell, a raised spiral in which the coiled tube is itself diminishing in diameter while the spiral diameter is also diminishing. The length of the tube if uncoiled would be of the order of 30 mm. It is full of fluid and is divided into an upper and lower chamber by a membrane, called the basilar membrane, and a bony shelf (the 'screw thread' of the central conical bone that supports the cochlea). The width of the basilar membrane changes along the tube of the cochlea and tapers in a reverse direction to it. That is to say, it is *narrowest* (of the order of 0·16 mm.) at the wide end of the tube, at the oval window, and *widest* (of the order of 0·5 mm.) at the apex of the tube. These figures give an idea of the smallness of the whole cochlea—the total length of the tube being about equal to the diameter of a penny. But this is not all. The upper chamber is again divided all the way along by another membrane—the Reissner membrane—crossing from the bony shelf, at an angle with the basilar membrane, to the edge of the tube. Inside the space between the two membranes is a series of tiny organs making up the 'organ of Corti'. (See Figs. 1 and 2.)

The nerve fibres that go to the brain start in the organ of Corti in minute hairs that project into the fluid and are embedded at their 'free' ends in a loose covering flap called the tectorial membrane.

Hearing obviously must come from these

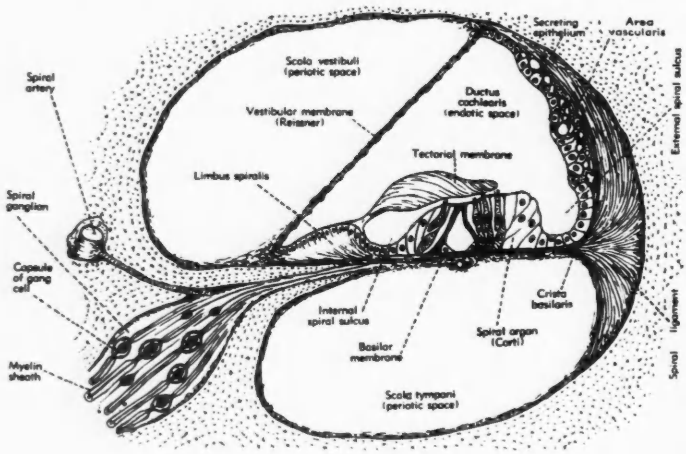


FIG. 1. The cochlear tube (or canal) in cross section. It is divided by the basilar membrane and the vestibular (Reissner) membrane. Note the organ of Corti (labelled 'Spiral organ').

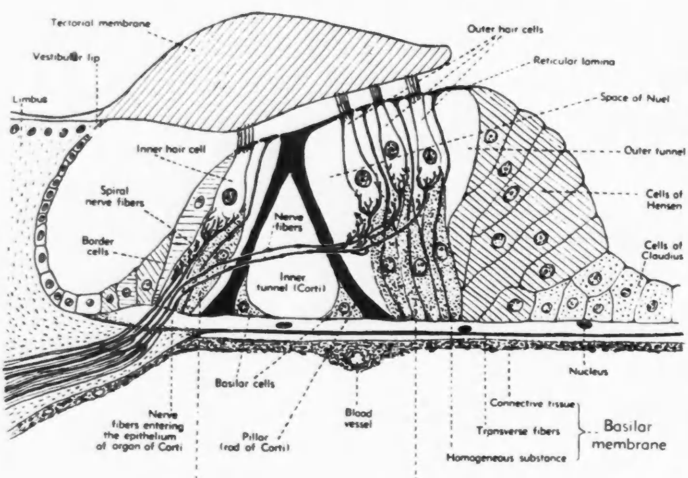


FIG. 2. The detailed structure of the organ of Corti.

hairs. It is generally agreed that fluid movements from the oval window cause corresponding movements of the basilar membrane, and these in turn bend the hairs, which resonate according to their length and stiffness, so that they respond selectively to different frequencies in the vibrations transmitted through the fluid. Yet the movement of the basilar membrane is fantastically small—at the threshold of hearing it is estimated to be less than the diameter of a hydrogen atom. The energy of the stimulus causing this movement is of the same order as the energy involved in the random movements of molecules in a fluid at normal temperatures.

The question therefore is: How do such tiny movements and energies stimulate a nerve fibre? It is known that the nerve action is all or nothing; if the stimulus is too small, no nervous impulse whatsoever is produced, but once the stimulus is large enough it triggers off a full-sized electrical discharge. Once that stage has been reached any increase in the intensity of the stimulus has the effect of merely increasing the frequency of the impulses, a characteristic of all sensory nerve action. So each stimulus merely triggers off a release of stored energy. Even so, the problem remains of explaining how the infinitesimal bending of the hairs of the organ of Corti triggers off nervous impulses.

Evidence about some of the electrical characteristics of the ear has been available for some years. It is accepted that an alternating voltage is generated in the cochlea and some time ago Professor Adrian suggested that this organ acts like a microphone in changing mechanical movement into electric variations. Dr. Davis has dubbed this generated voltage the "cochlear microphonic". Evidence arrived at independently with microelectrode techniques* by a worker at Harvard and another in Dr. Davis's laboratory supports the view that the source of this cochlear microphonic is in the Corti hairs.

The question recurs: How does this arise? Work by G. von Békésy at Harvard has provided evidence that is remarkable. The first part of it, published in 1951, is that if the tectorial membrane is displaced and then held in its new position, what was previously the A.C. cochlear microphonic has become a *direct-current* (D.C.) potential, and the total electrical energy in the resulting current-flow is much greater than the total mechanical energy used in moving the tectorial membrane and the organ of Corti. In other words there is evidence of an *amplifier* action.

The evidence immediately suggests that the cochlear microphonic voltage is not a pure alternating current but *a variation in a direct current*, for the movement of the tectorial membrane bends the hairs, and a movement in one direction only, as made in the experiment, would then mean merely a change in the D.C. potential.

A still more startling discovery was made by von Békésy in 1952, and verified qualitatively by one of Dr. Davis's team. It was the existence of a D.C. potential of the order of 80 millivolts between the cochlear compartment containing the organ of Corti and the other two channels.

On the basis of these experimental results Dr. Davis has constructed his hypothesis. It is that the bending of the hairs causes a change in the electrical resistance of the cells of which they are part—a bend in one direction increasing the resistance and a bend in the other direction decreasing the resistance. At the same time a D.C. potential is generated by the metabolic processes of the stria vascularis, in Fig. 1 called the *area* vascularis, which lines the wall of the cochlea between the membrane of Reissner and the basilar membrane. Movement of the hairs therefore causes a variation in the current flowing through the hairs, and this variation is what has been called the cochlear microphonic voltage, which is the immediate stimulus that results in a message being received in the brain.

In more everyday terms, the hearing mechanism of the inner ear consists of a transducer and an amplifier both together. Dr. Davis's own analogy is that the cochlea is, in its action, like a carbon microphone and battery. It is a bold hypothesis, and there is still much work to be done on the details. So far no hard facts have made the hypothesis untenable. If it proves true it will be the first acceptable explanation of the mechanism of hearing.

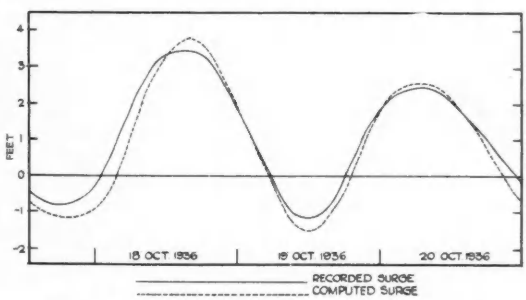
* These techniques, in which a minute electrode is used to probe nerves and tissues, the resulting voltage being greatly amplified, are widely used today in research on the sensory cells and nerves.

SCIENTIFIC PROBLEMS OF SEA FLOODS

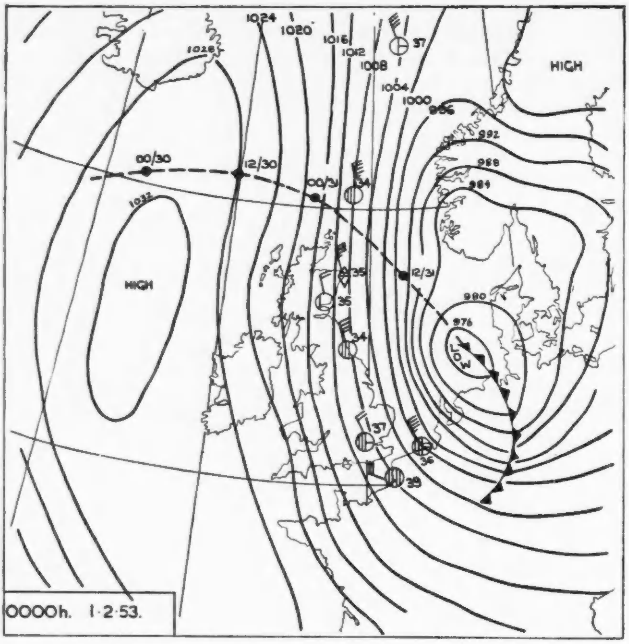
The sea has bitten deep into British history, and this factor has naturally affected the pattern of development of British science. Over the years many British scientists have been attracted by marine and maritime problems, and one immediately thinks of pioneer work done in this country on tidal phenomena, and in the fields of ship design and navigation.

Storm conditions have been intensively studied by British meteorologists. But since devastating sea floods caused by storm surges are relatively rare, the scientific knowledge which exists in this country about this phenomenon and the damage that can be created when the surges hit our coast is relatively scanty.

After the patching-up of the coastal defences damaged by the sea on February 1 had been done, there was a call for action to be taken to prevent the devastation caused by the sea floods ever happening again. A whole range of scientific problems arise in connexion with the disastrous floods. Some of them, such as that of restoring sea-flooded farm



The height of the Southend surge (October 17–20, 1936) as calculated by scientists of the Liverpool Tidal Institute closely matched the actual height recorded by the tidal gauge. The solid line is the graph for actual height; the dotted line was obtained by plotting the computed figures.



The storm surge of February 1 was associated with a depression. The track of that depression is shown by a broken line in this weather chart copied from the Daily Weather Report. *(By permission of the Controller, H.M. Stationery Office.)*

land to production, are relatively simple. Others, such as the problems involved in the organising of a system for forecasting where particular storm surges might cause breaches in the coastal defences, are much more difficult: readers will find an authoritative statement about this matter of forecasting the repercussions of meteorological factors upon tide levels in Dr. Deacon's article.

The scientific experts seem to be reasonably optimistic with regard to the restoration of flooded land. They have high hopes that the technique of using gypsum to reduce the high concentration of sodium ions which can be so destructive of soil structure. It is too early to judge whether this promising technique will give the results that are being claimed for it. But what does seem certain is that for the first time in Britain all the work of restoring flooded land will be closely watched by agricultural scientists, including soil chemists and soil physicists, so that it should be possible to collect all the information required to develop a completely satisfactory technique that can be used in the future wherever farm lands are flooded by sea water.

Plenty of problems with scientific aspects have to be considered when plans for improving our coastal defences are being drawn up. The Government is to be congratulated on setting up a strong committee to go into all these matters. (The membership of that committee and its terms of reference are given in this month's "Far and Near".)

But it is virtually impossible to visualise sea defences being so perfect that they give complete protection. The possibility of flooding in the future can therefore not be ruled out, which leads one to the question: Can the tidal and meteorological conditions which together brought about the exceptionally high waters that breached our coastal defences in February be recognised early enough to make feasible a system of forecasting whereby places likely to be affected by sea floods are warned well in advance of the arrival of the waters?

The effect of weather on the sea and the creation of storm surges have not gone unstudied, of course, while a good deal is known about the effect of individual storm surges on tide levels at different points along the coast. Thus, for example, after the Thames floods of January 1928 scientists of the Liverpool Tidal Institute analysed the nexus of meteorological and tidal factors which produced the exceptionally high level of the river. Their work showed that a storm surge originating in the North Sea can travel down the east coast of Britain like a tidal wave, taking about nine hours to reach Southend after the time it left Dunbar. In 1936 the Liverpool Tidal Institute predicted the passage of a similar surge; and the diagram on page 137 shows how closely the computed level of the surge and the level of the recorded surge matched. If all surges were of exactly the same pattern, it would be possible to predict excessively high water levels with considerable accuracy and useful flood warnings could be based on such predictions. But as K. F. Bowden of the National Institute of Oceanography says in an article in the March 1953 issue of *Weather*, in which he discusses the surge which caused the February floods, the storm surges which pass along Britain's east coast do not all follow one fixed pattern. Accurate forecasts of the effects of a storm surge at different points along the coast cannot be made at the present stage of our knowledge, and there is evidently plenty of scope for much more research to be done on the meteorological conditions involved in storm surges, and on the extent to which storm surges alter tide levels.

(The diagram on p. 137 comes from *Waves and Tides* by R. C. H. Russell and Cdr. D. H. Macmillan, published by Hutchinson's Scientific and Technical Publications.)

DESTRUCTIVE SEA WAVES AND SURGES

G. E. R. DEACON, D.Sc., F.R.S.
Director, National Institute of Oceanography

The surges that bring disaster to coastal regions are caused either by storms at the sea surface, or by seismic disturbances at the bottom. The popular name 'tidal wave' is used for both types of surges, but it is not a good name, because a tide is something that occurs regularly, and in the sea its regular rise and fall is caused by the moon and the sun. It would be more reasonable to call the storm effect a 'storm surge', and that of the earthquake or volcanic activity at the sea bottom a 'seismic surge', or, since this is more like a large wave or series of waves, the name 'seismic sea wave' might be better. (There is no complete agreement among scientists over the terminology appropriate to this seismic phenomenon; most commonly the Japanese name *tsunami* is used for a seismic wave, but it is time we had a more eloquent word of our own.)

In Britain we are most interested in storm surges, but many of the accounts of sea damage from other countries refer to seismic waves. The damage at Lisbon following the earthquake of 1755 was mainly due to a great rush of sea-water. Close to the centre of a submarine earthquake a ship is likely to feel a powerful shock as though she had struck a reef, and there are many accounts of damage to masts and rigging. There are also records of great disturbances in the water attributed to submarine volcanic activity, and there is little doubt that ships have been overwhelmed in such upheavals; indeed a Japanese survey ship was presumed lost in this way only a few months ago. At a distance from the earthquake's centre the damage is caused by a wave, or more often a number of waves. In deep water the seismic waves may be only a foot or two high with 120 miles between successive crests, and a ship at sea will not notice them. But as they slow down on approaching a coast they gain in height and consequently do more damage. The first indication of their approach is often a wave trough; this effect has led to the loss of many lives because the local residents, finding an unusual stretch of beach or reef uncovered, have gone out to look or to catch fish in the shallows. In the Pacific Ocean, scientists of the United States have organised a system to give warning of seismic sea waves; the intensity and position of the submarine earthquake are calculated from seismograph records, and nearby islands are then warned that a wave is approaching. At the same time they are asked for information to pass on to other islands.

Before passing on to the storm surges, it is worth mentioning a number of less spectacular wind effects which are a considerable nuisance to shipping and coastal engineers.

Many of our estuaries and harbours sometimes experience minor surges in which the water flows and ebbs several feet in as many minutes, causing great confusion and some damage among the small craft that are moored there or lying on the beach. There are local names for such occurrences; for example, 'boar' at Plymouth, 'run' or 'sitch' in the River Yealm, and 'sea bear' on the Baltic coast of Germany, where they are a real danger to fishermen. Such surges are not fully understood, but are generally associated with the rapid movement of a sharp change of barometric pressure and wind over a shallow sea. A minor surge of this type occurred on the south coast of Devon in July 1946, when boats were torn from their moorings and some damage was caused.

Other harbours are subject every now and then to another kind of backward-and-forward surging known as 'range action'. The size and shape of the harbour, as well as its position, have something to do with the setting up of a one- to three-minute oscillation in sympathy with a natural oscillation outside. The cause of the natural oscillations is again not fully understood, but they appear to be associated with the varying transport of water by groups of high and low waves towards a shelving beach, or across a bar. They may also be due to long waves travelling directly from a distant storm. The fluctuation of water level in the harbour is at most a foot or two, but the backward-and-forward swing is sufficient to snap mooring lines if these are not continually tended. There are one or two harbours that can be so bad that ships have to cast off and put to sea to escape damage.

STORM SURGES

The foregoing phenomena are less serious on the whole so far as Britain is concerned than the next category of surges—the *storm surges*. The most obvious effect of the wind is to produce the waves which themselves do much damage to ships and coast defences. Although the natural slopes of sand and shingle that protect much of our coast are built up by the long smooth swells that roll in from distant storms, the rough, steep waves that are most

prevalent in winter tend to drag the beach material away and cut into the land. As time goes on the difficulty of maintaining a coast seems on the whole to increase. As more and more of the coastline is protected, the remainder seems to become more vulnerable, and the general standard of protection has to be raised. Also, as the amenities of the coastal fringe are exploited there is more easy spoil for the sea, and more demand for protection. When a town or village is threatened we hear about it, but most of the crumbling and falling that goes on, although the repair work adds up to millions of pounds each year, attracts little attention. Usually the local engineers and their labourers manage, in spite of bad weather and soft ground, to prevent anything spectacular.

But not always. Sometimes the sea does its worst. Superposed on the normal rise and fall of the tides, and underlying the ordinary storm waves, there is a rise in water level that no reasonable defence can withstand. History has many such records. In the Middle Ages the Low Countries suffered terrible inundations. In one, 100,000 lives were lost, and today the drowned villages, the reeds and the mosquitoes of the Biesbosch, beyond the Moerdyck Bridge, are still a reminder of what would happen if the efforts now being made to restore flooded areas were to fail. In the early 18th century 300,000 are said to have been drowned by a disastrous surge from the Bay of Bengal, and only fifty years ago there was tremendous damage and a loss of 6000 lives when Galveston, Texas, was flooded by a hurricane. These are the worst examples among many serious disasters which, till the recent floods, have fortunately become rarer and less severe.

It is convenient, when one is visualising the storm surges that affect our coasts, to compare the North Sea with a shallow dish in which the water rocks from side to side as well as from end to end, and to imagine it as joined to another, and larger, dish, the Atlantic Ocean, which is also very much alive. In relation to its effect on our shores there are three main factors to be considered: the effect of wind near the place of observation, the effect of the wind over the major part of the sea, and the effect of travelling surges entering the sea from outside. Each depends on the rate of change of wind and the depth of water, as well as on the strength of the wind, and all these factors interact with each other. Disasters occur when all three reinforce each other and produce a peak near high tide.

The meteorological disturbances cannot be predicted in such a quiet and businesslike way as the tides. The tide-raising forces depend on the relative positions and movements of the earth, moon and sun. These obey well-known laws, and, thanks to careful and patient study, they can be calculated years ahead. It is not easy to work out their effect on the water level at particular places, but once the changes of water level have been recorded and related to the forces involved, the heights of high water can be predicted—in the absence of meteorological disturbances—to within a few inches and the times of high water to within a few minutes. Thanks to their skilful development of methods and machines, Dr. Doodson and his staff at the Liverpool Tidal Institute, numbering not more than fifteen in all, can satisfy the demands of more than a hundred places in all parts of the world a year in advance, and, although working reasonable hours, they manage to do a great deal of research work as well.

The staff of the Tidal Institute are, of course, well aware of the importance of meteorological effects. One of their reports, describing winter conditions at Southend, shows that one in fifty of the measured high-water levels is more than two feet different, higher or lower, than the predicted tide; such differences are naturally less in summer.

The interaction of the storm surges with the tides may cause sharp peaks of water level. The greatest elevation of the water above tidal level known since 1911 was more than eleven feet above the prediction for December 31, 1921; it was, however, a sharp peak and it occurred quite harmlessly two hours after low water. The elevations above the tide which occurred in January and February this year were not so great but they lasted longer and occurred near high water and so had a much more catastrophic effect.

No one can say when there will be another dangerous surge since so many factors are involved; it might be next year, it might be in a hundred years. There was a bad one in January 1881, which *The Times* described as calamitous and, as far as London was concerned, that of January 1928 was even more serious.

No one can expect a knowledge of the meteorological effects anything like so precise as our knowledge of the tide-raising forces, but the staff of the Tidal Institute have disentangled many of the factors involved and have recognised a number of distinctive types of weather distribution, and with the help of weather forecasts for the North Sea and weather maps for the adjoining ocean they have shown that useful predictions could be made. The theoretical work on which their calculations are based is a specialised branch of fluid dynamics and well beyond most people.

But to make regular predictions of the sort of conditions to expect around our coasts, the kind of forecasts which would necessitate making allowances for all the meteorological effects that alter the movement of the sea would be very different from the almost routine work of the Tidal Institute. It would mean that during the winter months the meteorological situation and tidal records would have to be watched day and night, and any spare time would be needed to improve the methods and understanding of the problem. Local forecasts would have to be made as well as comprehensive ones. There are already forecasts for the German Bight.

Apart from flood warnings, forecasts of the meteorological disturbance of the tide would be useful to shipping and harbour boards; an extra foot of water might allow a vessel to catch a tide, whereas a foot too little could be dangerous. The pilots would no doubt still tap their own barometers and use their own signs and portents, but only good could come of a better understanding of the effect of wind and weather.

(This article contains the substance of Dr. Deacon's "Science Survey" talk, broadcast on March 19. For further reading on this subject, readers are referred to R. J. Corkan's paper, "Sea Surges", The Dock and Harbour Authority, February 1948.)

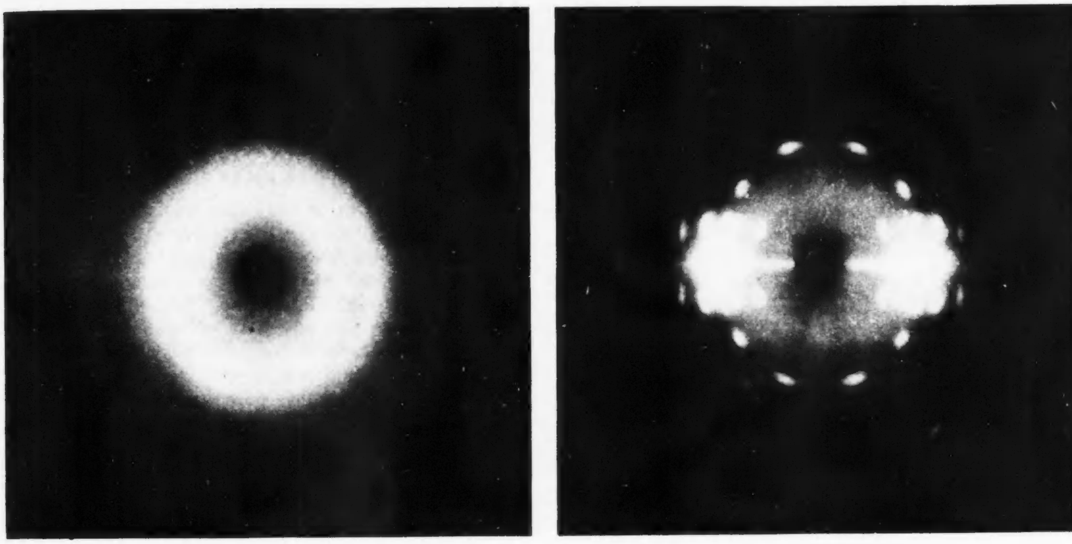


FIG. 1. The examination of X-ray diffraction patterns plays an important role in the systematic search for synthetic chemicals capable of conversion into textile fibres. These two pictures show patterns obtained for Terylene. The left-hand one is typical of spun Terylene filaments, in which the material is non-crystalline and unorientated. When the filaments are stretched, in the process known as *drawing*, the pattern changes, as revealed in the right-hand picture; the material here is crystalline and well orientated. (*Photographs by courtesy of C. W. Bunn and "Endeavour".*)

ARTIFICIAL FIBRES

R. W. MONCRIEFF

B.Sc., F.R.I.C., F.T.I.

In the first half of this article, published last month, the development of the various types of rayon was discussed, and also alginate fibres and Ardil. This instalment deals with the discovery of other synthetic fibres, including nylon and Terylene which followed the fundamental work on the molecular structure of fibrous materials using the methods of X-ray analysis.

Those fibres that we have discussed up to now have been made by taking some naturally fibrous or protein material, dissolving it and regenerating the fibrous material as continuous filament by a spinning process. Thus, in the search for artificial silk the best approach was to start with naturally fibrous material.

The possibilities of fibres from entirely synthetic substances were, until fairly recently, very remote. The reason was that before 1925 we had little or no idea of why a fibre was fibrous. At that time, from amongst the half-million chemical compounds that were known, only three were familiar in fibrous form. *Cellulose* (cotton, flax, jute, etc.) was one; *keratin* (wool, mohair, alpaca, etc.) was another, and *collagen* (real silk) the third. The analysis of fibres proved to be very difficult. Chemical analysis, for example, was unrewarding because natural fibres gave variable results; thus the sulphur contents of two wool fibres from the same lock of wool might be 1% and 3%.

The chemists' difficulties were unexpectedly resolved by the physicist. In the years preceding 1925 there had been a great deal of activity in the determination of crystal structure by X-ray analysis. No one could ever hope to *see* how the molecules were arranged in a crystal, because the molecules are so very much smaller than the wave-length of light. However, the wave-length of X-rays is very much shorter than that of light, and as X-rays will register on a photographic plate, they provided a new tool with which to attack the problem of molecular structure. It was found that if a beam of X-rays was directed on to a crystal, part of the beam passed straight through, but part was deflected. It was thought that the deflection was caused by the layers in which the constituent atoms arranged themselves. The angle of deflection of the beam could be measured, and the spacing between the layers of atoms could be calculated.

The method was applied in 1925 by O. L. Sponsler and W. H. Dore to analyse ramie fibres. Dimensions were measured, large-scale models were built to find how the atoms could be so arranged that the spaces between the layers would agree with the distances found by X-ray analysis.

FIBROUS MOLECULES

The surprising conclusion emerged that ramie and other cellulose fibres all possessed molecules that were very long in relation to their breadth. The one very obvious characteristic of any fibre, whether it be cotton, silk or wool, is

that it is long and narrow. Its molecules are similarly shaped, and they lie with their lengths more or less parallel to the length of the fibre. The possession of very long, chain-like molecules characterises substances capable of forming fibres. Later, W. T. Astbury and others carried out similar work on hair fibres, mainly on wool, and they found that here also the molecules consisted of long chains. By 1931, W. T. Astbury and A. Street had reached the following generalised conclusion from the facts which applied to particular fibrous substances: "The combined evidence of chemical and X-ray analysis, when brought to bear on the problem of fibre structure in both organic and inorganic fields, is undoubtedly leading to a relatively simple generalisation; in fact to a conclusion no more profound than that fibres are what they are because their inner molecular structure is also of a fibrous nature."

There was, nevertheless, still a great deal to be found even after the discovery that the molecules of fibres were themselves long and narrow, and it was then that the chemists were able to make their most useful contribution.

CHEMICAL ANALYSIS OF FIBRES

The French chemist, A. Payen, some eighty years ago was the first to appreciate that most vegetable materials were composed not only of starch but of a common substance to which he gave the name 'cellulose'. Payen showed that when cellulose was boiled with acid, glucose was formed. Much later it was shown that *only* glucose is formed. When Sponsler and Dore made their classic X-ray examination of the ramie fibre and built their model of the cellulose molecule, they found that there was a unit which repeated constantly in the long molecular chains; furthermore, and most significantly, this unit had exactly the same volume (169×10^{-24} c.c.) as the glucose molecule was known to have. The inference which was correctly drawn was that the cellulose molecule was built up of a chain of glucose molecules.

Later Sponsler and his colleagues, and H. K. Meyer and H. Mark, amongst others, showed that the cellulose in cotton, hemp and wood was similarly constituted. In fact all the vegetable fibres, cotton, jute, hemp, ramie, sisal, manila and the others are built up of long-chain molecules; the links or units in the chains are glucose molecules.

Wool and the other hair fibres were also investigated. These fibres also consisted of long chains, but here the links were not glucose molecules but amino-acid molecules. Chemically, glucose and amino acids are poles apart, and it is therefore not surprising that cotton and wool have such different properties.

STRUCTURE OF REGENERATED FIBRES

When Chardonnet, in 1883, had made his rayon out of cotton; when Courtaulds made their first viscose rayon in 1904; when Henry Dreyfus made cellulose acetate fibres about 1921, all this was unknown. The manufacture of artificial silk or rayon in enormous quantities was under way years before fibre structure was understood, but the intuitive empirical approach of using a *fibrous* raw material was essentially sound and it yielded wonderful results. All that was necessary was preservation in a reasonable measure of the long-chain molecules throughout the chemical processing. (Even today, despite the utmost care that is taken in the manufacture of viscose rayon, the chain molecules in the raw material, e.g. wood, may contain on average some 9000 glucose molecules, whereas in the finished rayon the average number is only about 450, so that still considerable breakdown of the chains takes place during processing.)

NYLON AND TERYLENE

When once it was understood that the fibre-forming property was associated with long-chain molecules, the chemist realised that the synthesis of new fibres was within his capacity. Dr. W. H. Carothers, the American organic chemist, was the first to realise the essential simplicity of the problem. He reasoned that if he started with a material composed of molecules which on either end held groups that could react together, it would be possible to build up molecules of great length. It was this simplicity of outlook which enabled him to synthesise nylon.

There are a great many chemical compounds known which have mutually reactive groups on either end of their molecules. One of these that Carothers worked with is called ε-aminocaproic acid. This has the chemical formula:

$$H_2N.CH_2.CH_2.CH_2.CH_2.CH_2.COOH$$

It can be seen that at one end of the molecule there is an amino group $-NH_2$ and at the other end a carboxylic acid

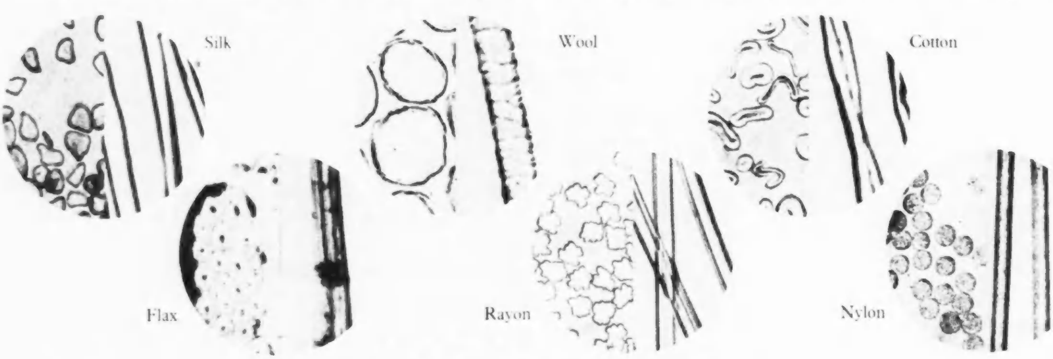
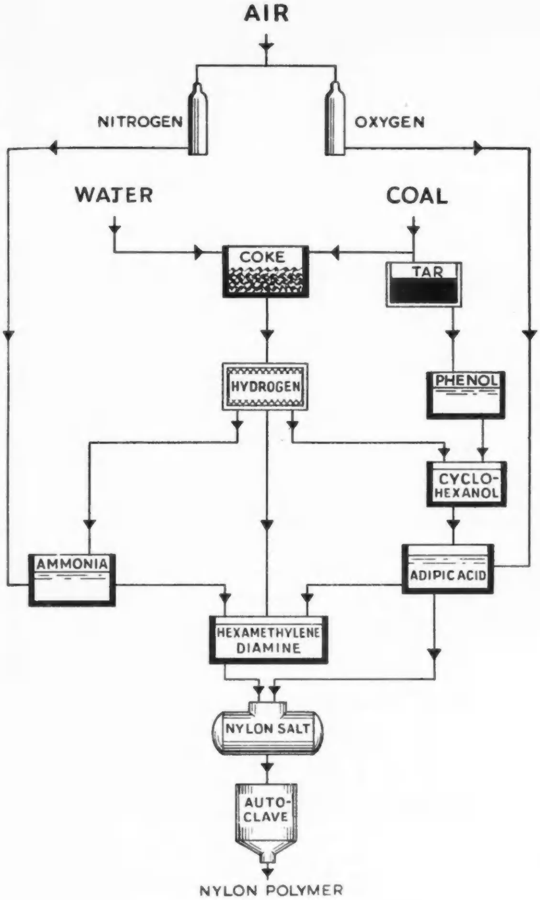


FIG. 2. SOME NATURAL AND SYNTHETIC FIBRES.



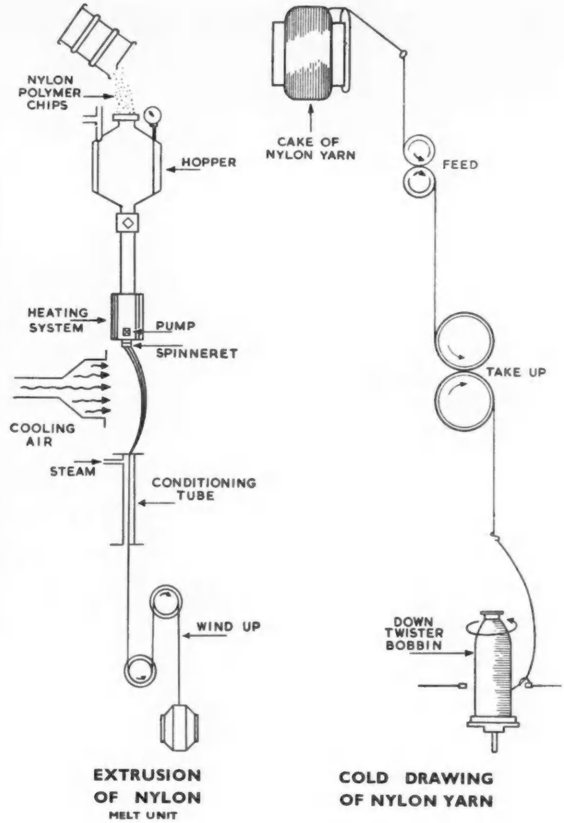


FIG. 3 (*left*). Stages in the synthesis of nylon polymer.
FIG. 4 (*above*). The production of nylon yarn from nylon polymer.

group —COOH. These two groups can react together in the way indicated below, which thus provides a mechanism for linking two or more aminocaproic acid molecules together:

$$\underset{\text{Acid}}{-\mathrm{COOH}} + \underset{\text{Amine}}{\mathrm{NH_2}-} \rightarrow \underset{\text{Amide}}{-\mathrm{CONH}-} + \underset{\text{Water}}{\mathrm{H_2O}}$$

Carothers found that when he heated aminocaproic acid under suitable conditions, two molecules could be linked in this way, to yield the simplest polymer of aminocaproic acid—that is the *dimer*, or polymer built of two molecules. Then two of the dimer molecules would react to give a *tetramer*. Larger and larger molecules were thus built up, and Carothers found that by the time this polymerisation process had yielded giant molecules each built up from about *100* aminocaproic acid molecules the material had good fibre-forming properties.

In practice it is not easy to make amino acids cheaply and the device was therefore adopted of reacting a diamine (or amine with two $-NH_2$ groups) with a diacid (with two —COOH groups), because these can be made cheaply, and they can be reacted to give a product almost indistinguishable from the polymer made from aminocaproic acid.

The diamine chosen was hexamethylene diamine which has the chemical formula:

$$H_2N.CH_2.CH_2.CH_2.CH_2.CH_2.CH_2.NH_2$$

and the acid chosen was adipic acid:

$$COOH.CH_2.CH_2.CH_2.CH_2.COOH$$

These two substances were reacted together, and the product polymerised; when about 100 molecules had linked up, a material was obtained which was capable of giving good fibres; all that was necessary was to melt it and pump it through fine orifices. The filaments so formed could be stretched to about five times their original length; unlike rubber, however, they do not retract when the tension is released. The stretched filaments are the familiar *nylon* fibre.

Terylene was discovered in this country by J. R Whinfield and J. T. Dickson. It is built up similarly to

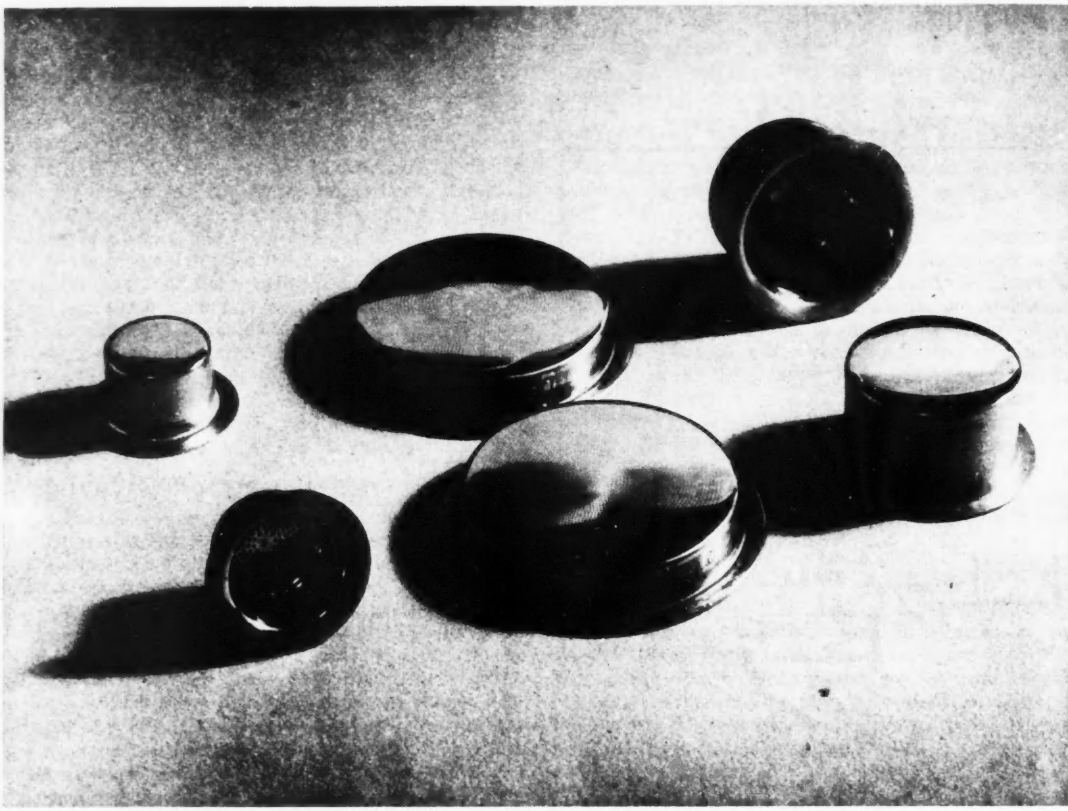


FIG. 5. Special non-corrodible materials are used for making the spinning jets required in the manufacture of synthetic fibres. This photograph shows spinning jets for viscose rayon manufacture in platinum-gold alloy and in stainless steel for acetate rayon. (*Courtesy, Johnson, Matthey & Co. Ltd.*)

nylon, but the starting materials are different. They are: *ethylene glycol* ($HO.CH_2.CH_2.OH$) and *terephthalic acid* ($COOH.C_6H_4.COOH$).

These two substances will react together, and polymerisation of the product gives polymers of increasing chain length. Once again when the number of molecules that have linked up is about 100, then one has a material with good fibre-forming properties. This Terylene fibre has also been made in America, where it is known as Dacron. It has many valuable properties, but perhaps the most intriguing fact about it is that fabrics made from Terylene feel like wool and are warm to the touch.

THE FUTURE OF FIBRES

When once the fundamental characteristic of fibres was understood to be their possession of long-chain molecules, it was clear that new fibres, different from any provided by nature, could be synthesised. Nature has used only two kinds of links for fibre synthesis: the link between glucose molecules in the cellulosic fibres, and the link which depends on amino acids and which is the basic feature of the structure of hair fibres and of silk. Already today fibres which involve several different kinds of links have been made; the outstanding ones are nylon and Terylene, but there are several others already on the market. New fibres are being made in the laboratories every week; some of these have fascinating properties, and a few of them will in the coming years be manufactured and offered to the public. The possibilities seem endless; one can foresee fibres that will hardly ever wear out, fibres of gossamer quality, fibres that will withstand the action of corrosive chemicals, fibres that will be waterproof, fibres that will be flameproof.

(The photomontage of Fig. 2 was prepared by the B.B.C.'s Publication Department, and includes photomicrographs supplied by the Shirley Institute, Wool Industries Research, and British Nylon Spinners Ltd.)

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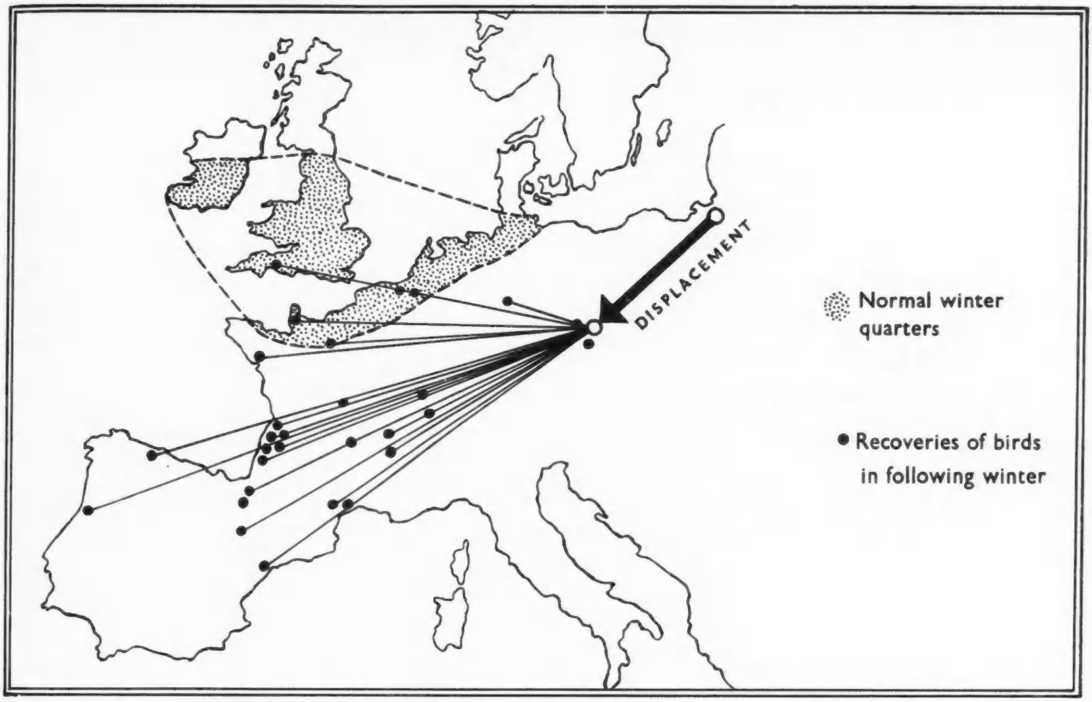


FIG. 1. Experimental displacement of young starling migrants in autumn. Observe the general tendency for the birds to continue on a parallel course to normal. (*After Kratzig & Schuz, 1936.*)

DIRECTION-FINDING IN BIRDS

G. V. T. MATTHEWS
M.A., Ph.D.

In human terms 'migration' implies dispersal from the original home and more or less permanent colonisation of another land. For the great majority of birds on the other hand, 'migration' is an activity firmly based on a permanent home, the place where the bird is bred and to which it returns again and again to breed. The extensive practice of marking individual birds with numbered aluminium leg-bands has shown clearly how restricted is this breeding area. In many species the area to which they migrate each winter is almost as limited in size. Their movements are rather like those fortunate people who leave London each autumn, spend the winter on the Riviera and then return to the metropolis in the spring.

Other species of birds, notably the oceanic petrels and albatrosses, may range far and wide when not breeding, but always return to the same small, isolated island to lay their eggs. This intense 'patriotism' poses many interesting problems; not least among them is the means by which the birds are able to find their way over hundreds or thousands of miles between home and winter quarters, and back again.

MIGRATION IN A FIXED DIRECTION

If birds are removed from the nest as eggs or nestlings, and are reared far away from it, they will adopt this new area for their home and return there to breed. Moreover, even if they come of non-migratory stock, they easily adopt the migration movements of their foster parents, if they are free to follow them. It therefore seems that birds are not born with any precise inherited conception of their ancestral home, nor of the wintering area. If the young habitually travel with the old birds, as do the geese, for example, it is easy to see how these traditions could be learnt by each generation. But in a great many species the young leave before or after the old birds, and there can be no question of the latter acting as guides—the cuckoo is an extreme example here. Evidence has accumulated that such birds possess an innate tendency to fly in a certain compass *direction*. Widespread observations of migrations in progress have shown that they occur over wide 'fronts', and that they are only temporarily canalised into concentrated streams by hills and coasts. (It was this concentration along valleys or shorelines that misled some observers

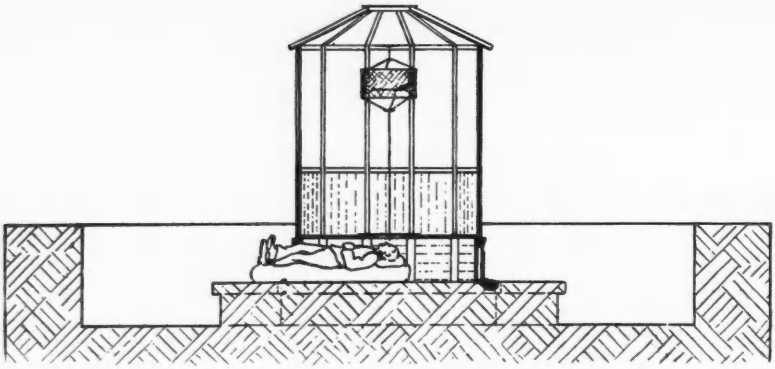


FIG. 2. Observing directional behaviour of a captive migrant in a circular cage within a glass pavilion. (*Kramer, 1950.*)

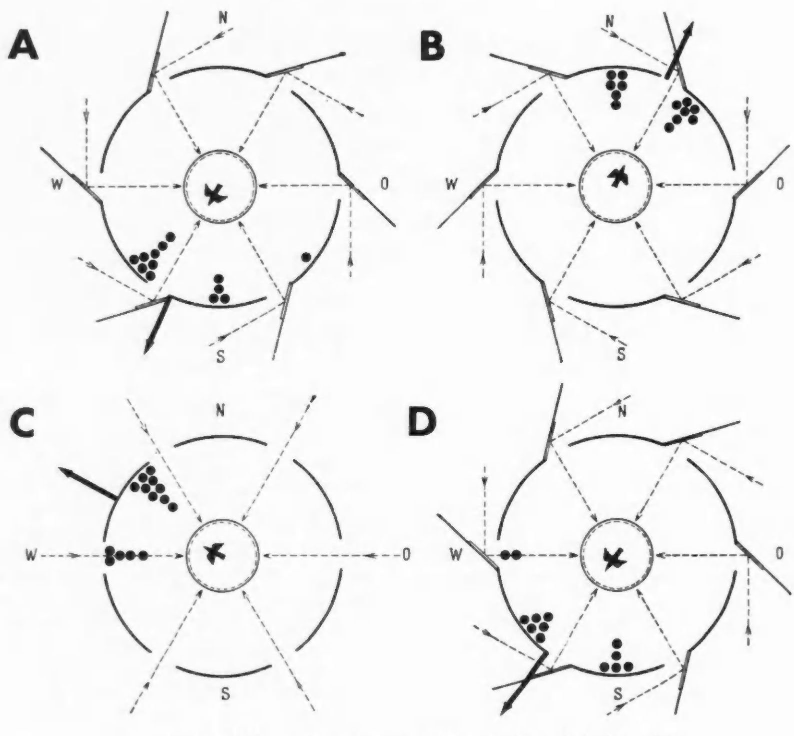


FIG. 3. In Kramer's mirror experiments, the orientation of a captive migrant alters with the change in the sun's apparent position. In C no mirrors were used, and the bird's average orientation during the experiment was in the direction of the arrow. (Each dot represents 15 seconds of activity in a particular direction: the average orientation represented by the arrow is the average of the different orientations recorded in the series of 15-second observations.) In A and D the arrangement of mirrors alters the sun's apparent position, by 90 degrees in an anti-clockwise direction in both cases; the bird's orientation alters accordingly. In B, the change is 90 degrees in a clockwise direction. (*Kramer, 1950.*)

into believing that the birds followed definite topographical routes.) Young birds on their first autumn migration have been trapped in large numbers and released several hundreds of miles away to one side of the main migration axis. Those birds recovered the following winter were found to have continued to migrate roughly parallel to their original course. They ended up in areas outside those occupied by their compatriots (Fig. 1). Similar parallel displacements have been noted when the returning spring migrants have been treated in the same way, indicating that even at this stage the location of the breeding home has not been finally fixed. Having actually bred in a novel area, the birds adopted this as their home and remained 'displaced persons' for the rest of their lives. The tendency to fly in a predetermined direction is still clearly seen where there is no possibility that the displaced birds joined forces with others of their species passing through the release point. The innate nature of such a tendency is further shown in an experiment in which young storks from East Prussia were reared in the Ruhr and held back until their foster parents and all local storks had departed in their migration, which was in a south-westerly direction. But the young storks when released travelled south-south-east, their progress being plotted from visual reports of these brightly marked birds. This is the direction in which storks normally migrate from East Prussia.

USE OF THE SUN AS A COMPASS

Recently it has been shown that if migrants are kept caged during the migratory season, their restless movements and flutterings have a strong tendency to be orientated in one general direction—that in which they would have been flying if free (Fig. 2). This gives a laboratory technique for studying how the birds determine the direction they automatically try to follow when migrating. The movements of captive starlings became quite random when the sky was overcast with heavy cloud. Further, when the apparent position of the sun was altered by an arrangement of mirrors (Fig. 3), the direction of the bird's movements altered so that they bore the same relation to the new 'position' as they did to the old. The birds would even orientate in a closed room with reference to a powerful electric lamp placed so as to subtend the same vertical angle as the sun did at that time of day. There seems no doubt, therefore, that these birds were using the sun as a compass.

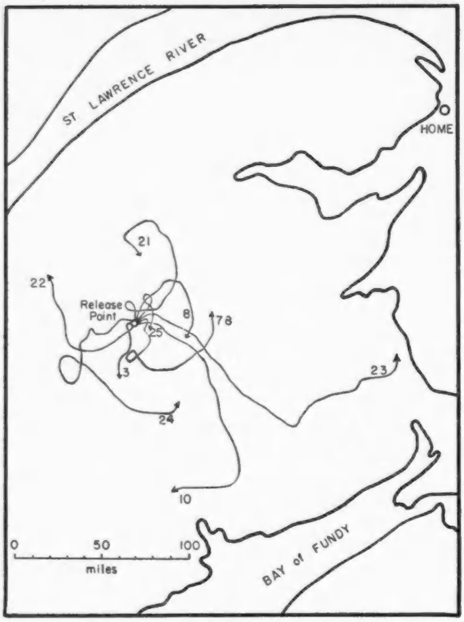
Since the orientation was constant whatever the time of day, they must be able to appreciate and allow for the sun's apparent diurnal movement. Birds can also be made to *learn* to move in a given direction, again using the sun as their reference point. This is a partial basis of homing in racing pigeons; here the release points are commonly arranged at increasing distances along a straight line. In these simple one-direction movements, whether they are innate or acquired, occasional glimpses of the sun would be sufficient to keep the birds on their course. Migration in cloudy weather, therefore, does not necessarily imply some other method of orientation. Similarly, it is possible that birds of species that migrate at night orient themselves by the position of the sun at its setting.

We can now understand how young birds are able to arrive in the appropriate winter quarters without old birds to guide them. We have less precise ideas about why the birds call a halt there and do not continue flying indefinitely in the same direction. But we know that the innate urge to migrate lasts for only a few weeks, and this may determine, roughly, the distance travelled.

HOMING AND TRUE NAVIGATION

The bird's instinctive equipment will see it through its first complete migration. In later years it will be travelling between areas of which it has had previous knowledge. The question then is whether the bird remembers the route it has used; will it be able to memorise the landmarks seen on its previous journeys, and simply 'map-read' its way? In many cases this does not seem to be credible, because the journeys are so long, or are made at night or over the open sea. Even a migration of a few hundred miles over a continental area would require the bird to memorise an immense amount of detail. Of course the simple form of sun-compass navigation shown by the young birds would still be of assistance. But when old birds were subjected to displacement experiments they tended to regain their normal areas, and *not* to fly blindly on. There is also a great mass of evidence from 'homing' experiments in which birds are removed, usually from the nest but sometimes from the winter quarters, and released at a distance. A considerable proportion return, and this happens even when the birds are released outside their normal range, which entirely eliminates the possibility of 'map-reading'. Moreover, a tendency to fly in one direction would be worse than useless when releases are made from all points of the compass. Many astonishing journeys have been reported; the most remarkable was the return of a Manx Shearwater 3050 miles across the Atlantic to its burrow on Skokholm Island Bird Observatory, Wales.

In general it has been found that the percentage of successful returns fell off with increasing distance, and that the gap between release and return was considerably greater than that needed to fly straight home. These facts encouraged the idea that birds released in an unknown area wander at random until, by chance, they come across a known landmark and so reach home. It can be demonstrated mathematically that this theory is not so far-fetched as it may seem. In one case the actual tracks of homing birds—gannets, to be specific—were observed from a light aircraft (Fig. 4) and did not give any impression of directed flight. But gannets are very dependent on air currents for progression, and the search for suitable soaring conditions may have overshadowed their search for home. Recently work in this country has demonstrated conclusively that at least three very diverse species of birds—Homing Pigeons, Lesser Black-backed Gulls and Manx Shearwaters—are really capable of *navigating*. That is, they are able to fix the position of an unknown release point relative to that of their home, which may be in any direction. This was shown by carefully observing the individual birds at release, and plotting the bearing at which each was lost to sight in binoculars (Fig. 5). A concentration about the home direction is found, indicating that the birds had become orientated shortly after release. Secondly, a significant proportion of the pigeons and shearwaters



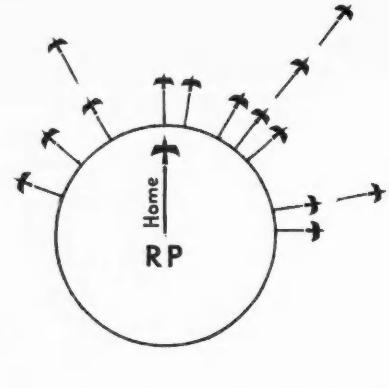


FIG. 4 (*left*). Actual tracks of homing gannets as observed from a light aircraft. There are few signs of a directional tendency towards home. (*Griffin & Hock, 1948.*)

FIG. 5 (*above*). After release, singly, in unknown country, pigeons are followed with binoculars until lost from sight between one and two miles from the release point (RP). The arrows indicate the bearings at which the individual birds vanished. Note the concentration of vanishing points around the true home direction, in this series of releases under sunny conditions.

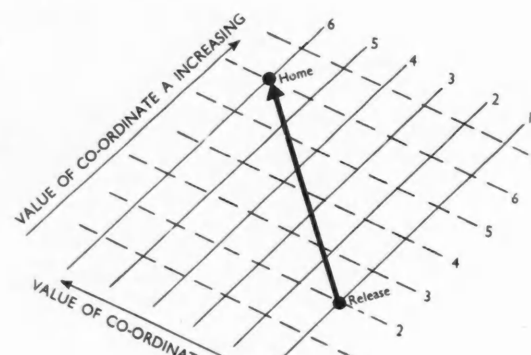


FIG. 6. Grid navigation. The release point has lower values of both A and B than has the home point. By moving up the resultant of both gradients, the bird could head directly home.

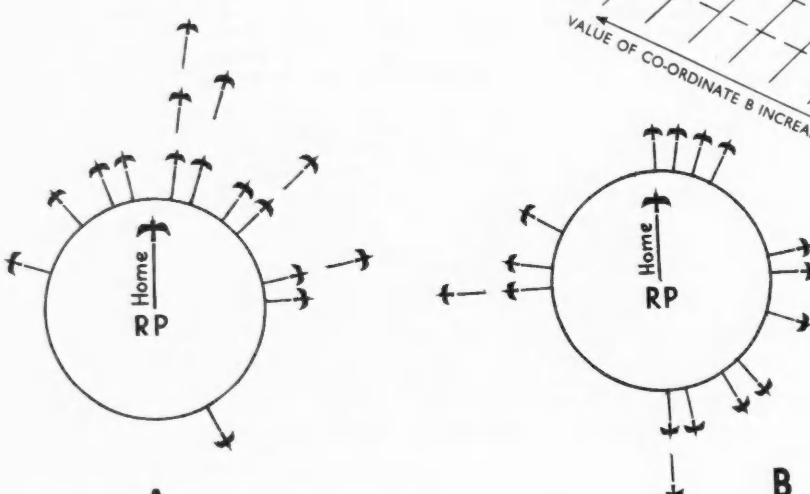


FIG. 7. Pigeons released from the same point as in Fig. 5, and observed and represented in the same way. (RP is the release point). In A the attachment of wing magnets did not disturb initial orientation. In B overcast skies resulted in a random scatter from the release point.

home so quickly that they must have flown almost straight across the unknown areas. This was so even when (as in the illustrated example) the release point was in the opposite direction from any previous experience. Thirdly, repeated use of individual pigeons showed a consistency of performance, good or bad, which would be expected if we were dealing with some definite faculty.

A large number of theories have been put forward to account for such navigational ability; most of these were proposed before the ability to navigate had definitely been established. Many of the theories are hare-brained, and in fact there are only four which merit serious attention. The first suggests an extension and refinement of the known capacity of the inner ear apparatus for appreciating changes in speed and direction. The bird was supposed to detect and memorise all the acceleration changes imparted on it during its outward journey in a box, and then regain home by playing the record backwards. It can be shown, however, that birds do *not* retrace the route by which they were taken to the release point. An elaboration of the theory is therefore necessary by which the bird is further required to carry out the process of triangulation needed to fuse the various displacements into one final appreciation of the home direction. Theoretically it is extremely unlikely that all this could be done by the organs at the bird's disposal, especially as it would be carried out against a background of much greater incidental accelerations such as those caused by the jolting of the transporting vehicle. There is also practical evidence against the theory. Homing has not been disturbed by disruption of the semicircular canals; nor has it been affected by transportation under heavy narcosis, or in horizontal drums that were rotated continuously. While none of this evidence is absolutely conclusive, it is sufficient to make further investigation of this theory unprofitable.

The other three theories all suggest some form of navigational 'grid'. The birds are required to detect and measure certain physical phenomena that vary regularly in a quantitative fashion over the earth's surface. By recognising the difference between the values at the release point and those obtaining at home, the bird could move up or down the gradient to approach the latter. Where two such gradients existed at an angle to each other (Fig. 6) the bird could proceed directly home by balancing the influences of the two phenomena.

THE CORIOLIS FORCE THEORY

The Coriolis force consequent on the earth's rotation varies regularly with latitude and has been suggested as one component of such a grid. The sideways velocity of a point on the earth's surface is much greater near the Equator than near the Poles. If therefore one could, say, fire a shot from the North Pole at a target on the Equator, the shell would arrive well to the right of the target, following a curved path. The amount of curvature increases towards the Equator, and hence the sideways force that must (by definition) be producing it also increases. The Coriolis force can be detected by the effect it has on liquid contained in a ring-shaped tube, which may be considered as a rough model of the semicircular canal of the inner ear. If the ring is rotated at right-angles to the earth's axis, the liquid in one half moves towards the axis, and that in the other half away from it. Consequently Coriolis forces acting in opposite directions are produced which result in a swirling of the liquid. The intensity of this effect is directly related to the latitude in which the ring is being rotated. Unfortunately it is difficult to see how this elegant theory could be translated into practice. It could hardly be of use to a flying bird, since if the latter's course altered by so much as 1/50th of an inch in 100 feet, spurious Coriolis forces would be produced, comparable to those of the earth. Further, when the ring-tube model is scaled down to the actual size of the bird's semicircular canals, the energy generated would be much less than the random molecular movements against which it would have to be measured.

THE MAGNETIC THEORY

The idea that birds are in some way sensitive to the earth's magnetic field, and use it in their navigation, has been current for about eighty years. A simple appreciation of the magnetic North would only be of assistance if the bird knew by some other means the direction in which it had to fly. For true navigation it would have to detect differences in the intensity of magnetic effects. The original theory was that the bird could detect the magnetic field directly and analyse it into its components of declination, inclination and intensity. There is no evidence of any organ in the bird that would be capable of detecting and analysing the magnetic field in this way. Birds in fact have proved to be completely indifferent to strong magnetic fields.

A modified version of the theory therefore suggests that the field is detected indirectly through its electrical effects on a moving bird. This also is unsatisfactory. If the effect was an electrostatic one, on a linear conductor moving through the field, then the induced voltage would be extremely small, and it would have to be measured against the incomparably stronger electrostatic fields of the earth and moving clouds. If the effect was an electro-dynamic one on a loop conductor (e.g. a semicircular canal) oscillated in the field, only a minute current would be produced, again to be measured against a background of much greater effects of the same nature, physiological currents in the body. Despite these strong theoretical objections, the idea was recently the subject of large-scale tests in America. These were, however, badly designed and badly interpreted, and show no support for the theory. The basic experiment of attaching magnets to the wings of pigeons to produce a pulsating electromotive force to confuse any measurement of that due to the earth's field has been repeatedly carried out. No effects on orientation or homing were demonstrated (Fig. 7).

THE SUN NAVIGATION THEORY

The third method of grid navigation, long used by human navigators, is the determination of latitude and longitude from the sun's position. It is a complication and extension of the method of using the sun as a compass employed by young migrants. A good deal of practical support for such a theory has accumulated recently. The initial orientation in unknown areas, mentioned earlier, is found to break down under conditions of overcast skies, and returns are both slower and fewer. This disorientation in the absence of the sun has been found whenever true

navigation has been demonstrated, in pigeons, gulls and shearwaters. It is not necessary for the bird to make an exact determination of its position on any day of the year. If it could appreciate whether it had been displaced north or south and east or west, this would give the general homeward orientation that has been observed, and a line of flight sufficiently accurate to bring it to the known area around home. To do this the bird would have to measure the altitude (vertical angle) and the azimuth (horizontal angle) of the sun's position; it would, moreover, need some reference point from which to measure the latter. We cannot allow it a magnetic compass, but the sun itself could play this part as we have seen. The highest point of the sun's arc is due south and is reached at local noon. The bird is seldom able to make the noon observation, so it would have to determine the highest point by observing the sun's apparent movement along its arc for a short while, and then extrapolating from this observed portion. Comparison of the sun's co-ordinates at the release point with those memorised at home would give the relative displacement (Fig. 8). Thus if the sun is lower at noon than at home, the bird has been moved north; if higher, it has been moved south. The detection of longitude displacement necessitates the bird having a very accurate chronometer giving its home time, just as this is required in human navigation. Animals are certainly provided with a good 'sense' of time, but it is not known how accurate such internal, physiological 'clocks' are. Displacement to the east will mean that the sun reaches its highest point before it would at home; when the displacement is to the west, that point will be reached later. (This can be expressed in another way: at a given chronometer time the azimuth angle is smaller or larger than it would be at home.)

This theory has the advantage that it does not require any special organ to have been evolved for this sole purpose; in addition, the one external phenomenon provides both the co-ordinates necessary for a navigational grid. (Mixed theories such as that of Coriolis-magnetic navigation which require the development of two special senses are particularly unattractive.) Nor is this theory made improbable by known physical limitations of the organs

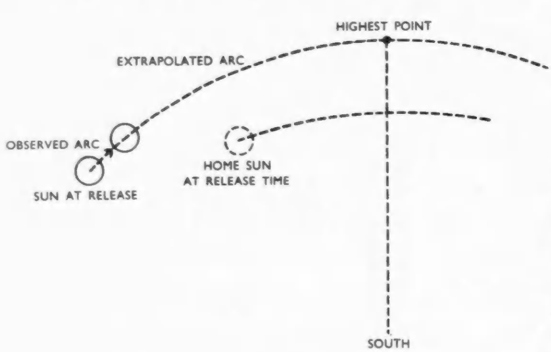


FIG. 8. Sun navigation. The sun at release has a greater altitude than the home sun, and is behind it in time. Release point is therefore south and west of home.

concerned. The angular differences to be measured are certainly small, but they are not beyond the resolving power of the bird's eye, which is also particularly adapted to the detection of movement. On the other hand, the theory credits the bird with a remarkable memory of the sun's position at home, and with the ability to interpret automatically several possible combinations of past and present observations.

The sun-navigation theory is certainly the most feasible one that has been advanced, and its details are under investigation both in this country and in Germany. One line of attack is provided by the seasonal fluctuations in the altitude of the sun, which simulate changes in latitude, and could confuse a bird prevented from seeing them before release. Another concerns the minimum time necessary for orientation after the first glimpse of the sun. A third is aimed at upsetting the supposed 'chronometer' that would be needed for longitude determination. The results of these researches have not yet been published, but it can be added that the general trend of the evidence available to date is in favour of the hypothesis.

The present picture of direction-finding in birds can now be summarised. The young migrant is equipped with an innate tendency to fly in a certain compass direction from the place where it was bred. That direction is determined by day migrants from the sun position, and it is possible that night migrants also use this method. The young bird is thus able to reach the normal wintering area without guidance from older birds. In some cases the return migration is also purely directional. Thereafter the home breeding area is fixed for the individual bird as a result of its own experience, and the wintering area may also be nearly as circumscribed. The landmarks of these areas, and to some extent of the country between them, enable the bird to pin-point its position. But when it strays from known areas, or is forcibly removed from them by an experimenter, it can navigate completely in the absence of known landmarks. Again the sun would seem to provide a basis of this more complicated direction-finding, its co-ordinates giving the bird's relative position in latitude and longitude.

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CAN MACHINES THINK?

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The subject of this article can be discussed on various levels, ranging from that of a sensational Sunday newspaper to that of a sober philosophical periodical. It arouses deep-seated emotions, and views are apt to be expressed with vigour.

Two contrary attitudes are common. In the first place there is a widespread, although mostly unconscious, desire to believe that a machine can be something more than a machine, and it is to this unconscious urge that the newspaper articles and headlines about mechanical brains appeal. On the other hand, many people passionately deny that machines can ever think. They often hold this view so strongly that they are led to attack designers of high-speed automatic computing machines, quite unjustly, for making claims, which they do not in fact make, that their machines have human attributes. Such people are often misled by the use of technical terms based on physiological analogies; a good example is the use of the word 'memory', for the part of the machine in which numbers are stored.

We must begin by deciding what a machine must be able to do in order to qualify for the description 'thinking machine'. An extreme view is that of Berkeley, who in his book *Giant Brains* says, after writing about certain automatic calculating machines: "A machine can handle information; it can calculate, conclude, and choose; it can perform reasonable operations with information. A machine, therefore, can think." The use of the expression "reasonable operations" appears to beg the question, but from the examples that he gives it is clear that Berkeley means actions which depend on the power of the machine to compare two quantities and perform one set of operations if they are equal and another set of operations if they are unequal. This, for example, would make it possible for the machine to consult a city directory which had been placed beforehand in its store, and to determine the block in which a house having a given address lay. However, other machines, such as automatic railway signalling systems, can perform this kind of "reasonable operation", and Berkeley's definition of what is meant by a thinking machine appears to be so wide as to miss the essential point of interest in the question, "Can machines think?" An alternative approach is to say that a machine is a thinking machine if it can imitate a human being. There are plenty of existing machines which will do this in a limited field; for example, a doctor friend of mine has a device which will answer his telephone in his absence and repeat a message he has previously recorded. But again, to describe this as a thinking machine would strike most people as playing with words and no more.

IMITATING HUMAN BEINGS

It is, however, undoubtedly the power of some machines to simulate human behaviour that people have in mind when they discuss this subject, and a machine which could pass itself off as a human being when given an extended test covering a wide range of different subjects might well qualify for the title 'thinking machine'. Among other things the machine would have to have some power of learning; for example, it should be possible for the examiner to play a game with the machine, having first explained the rules of the game. Of course, the machine need not necessarily have the physical appearance of a human being, and in order to avoid any unfairness arising on this account the test could best be conducted with the examiner in one room and the machine in another, the connexion between them being provided by a teleprinter circuit. The test would then take the form of a series of questions put by the examiner, with replies and counter questions automatically transmitted by the machine.

These ideas were first put forward by A. M. Turing in a penetrating article published in *Mind* (October 1950). The following example of a dialogue which might take place between the examiner and the machine is based on one given by Turing.

Examiner: Do you know the sonnet which begins, "Shall I compare thee to a summer's day"?
Machine: Yes.
Examiner: Would not "a spring day" do as well or better?
Machine: It wouldn't scan.
Examiner: How about "a winter's day"; that would scan all right.
Machine: Yes, but nobody wants to be compared to a winter's day.
Examiner: Would you say Mr. Pickwick reminded you of Christmas?
Machine: In a way.
Examiner: Yet Christmas is a winter's day, and I do not think Mr. Pickwick would mind the comparison.
Machine: I don't think you're serious. By a winter's day one means a typical winter's day, rather than a special one like Christmas.

The questions put by the examiner are supposed to be entirely unpremeditated so that there is no possibility of the answer being built into the machine on some sort of record. It is a fantastic suggestion that a machine should be able to carry on a conversation of this sort and many people will be inclined to reject it out of hand. Certainly no existing machine is in the least capable of doing anything of the kind. I would agree with Turing, however, that the ability to pass this test or something like it is what people mean, or ought to mean, when they talk about the possibility of a machine thinking. If ever a machine is made to pass such a test it will be hailed as one of the crowning achievements of technical progress, and rightly so. Whether everyone will then agree that the machine thinks is another matter; I suspect that to many people thinking means something which can be done by a human being, or possibly by an animal, but not by a machine. This, however, is leading us from a discussion of what machines can do to an entirely different question, namely, "Is the brain a machine?" This is a question on which science has hardly begun to touch

and the answer which would be given to it by any particular person would depend on his philosophical beliefs, particularly as to the relation between mind and matter. Indeed from one point of view, to say that the brain is a machine is equivalent to denying altogether, as some philosophers do, the distinction between these two things.

In some ways it might be said that people now tend more than they formerly did to regard human beings in the same light as machines. For example, the prevalent attitude to the delinquent is to regard him as the victim of circumstances and to say that he requires treatment rather than punishment. This is just the attitude one takes to a machine. One does not get cross with it when it does something wrong, but one looks for and rectifies the fault.

AUTOMATIC DIGITAL COMPUTERS

The subject of this article is not a new one, but its discussion has been greatly stimulated by the development of high-speed automatic digital computing machines, since these machines are capable of performing operations of much greater complexity than any machines hitherto available. I shall therefore give a description of their mode of operation with special reference to those properties which seem particularly relevant to the present discussion.

The basic operations performed by a digital computer are very simple—addition, subtraction, multiplication and such like—but the machine can be set up so as to perform a long sequence, or *programme* as it is called, of these operations one after the other. The complexity which so impresses the layman is in fact a feature of the programme, rather than of the machine, and the machine can be changed over from one kind of work to another by changing the programme. For this reason machines of this kind are sometimes known as *universal* machines. Given a suitable programme a universal machine can do anything which could be done by a specially built machine; for example, it can simulate the behaviour of an analogue device incorporating feed-back. It is therefore convenient to discuss the problem of mechanical thinking in terms of writing a programme for a universal machine, rather than in terms of building a special machine. It is, of course, assumed that the universal machine is provided with a suitable output organ for the work it has to do; for the purposes of discussion this can be a printer capable of printing figures and letters. A machine built specially for experiments in mechanical thinking would need to have a very large memory, or 'store' as it is perhaps better called, and its basic operations might be different from those of a machine intended for mathematical work, but the relation between mathematics and logic is so close that the differences would be unimportant from the point of view of general discussion.

Some of the basic operations which can be performed by a digital computer are 'conditional'; that is, their nature can depend on whether a certain number (perhaps one that the machine has just computed) is positive or negative, or whether one number is greater or less than another number. The effect of a conditional operation is that a choice is made in regard to the subsequent action of the machine; if the condition is not satisfied the machine follows a course of action specified by one section of the programme, whereas if it is satisfied the machine follows a different course of action specified by some other section of the programme. As an example of the use of a conditional operation, I will give a programme for calculating a square root by a method of successive approximation. Suppose we want to find the square root of the number N, and suppose we have a first approximation x_0; then a closer approximation to $\sqrt{N}$ is given by $x_1 = \frac{1}{2}(x_0 + N/x_0)$. A still better approximation can be obtained by applying the formula a second time, using the old value obtained for x_1 as the new value of x_0. This process can be repeated until it is found that the latest approximation does not differ significantly from the previous one, i.e. until x_1 and x_0 differ by a quantity which is not greater than ε (say). The numbers N, x_0 (the first approximation) and ε must be placed beforehand in the store of the machine. The store of a large machine can hold many hundreds of numbers and it is usual to number, for easy reference, the 'locations' in which they are held. It will be supposed that N, x_0 and ε are respectively placed in storage locations 100, 101 and 102. The programme then consists of the following sequence of operations:

No. of operation in sequence	*Operation*
1	Copy number in 101 into 103
2	Divide number in 100 by number in 101, and put result in 104
3	Add number in 101 to number in 104, and place result in 104
4	Divide number in 104 by two, and place result in 101
5	Subtract number in 103 from number in 101, and place result (neglecting sign) in 105
6	Subtract number in 105 from number in 102, and place result in 106
7	If number in 106 is negative, go back to operation 1; otherwise go straight on to operation 8
8	Print number in 101

Here the *seventh* operation is the conditional operation. This short programme might well form part of a much longer programme in which the calculation of a square root was necessary.

DISCRIMINATION

Clearly, conditional operations are very important in the present context since they give the machine a power of discrimination. The possibility of programming a machine to consult a directory, as in Berkeley's example, depends on the use of conditional operations. However, when a machine performs a conditional operation it can be said to think just to the same extent, and no more, that an Underground train can be said to think when it approaches points which have been set automatically by the passage of a previous train, and goes in one direction rather than another. The use of the word *think* in connexion with conditional operations would be justifiable only if the use of a convenient technical term were thereby secured. I know of no computing machine laboratory where the word is used in this way, although the somewhat comparable words *decision* and *discrimination* are sometimes used.

Before a programme such as that given above can be put into the machine it must be expressed in a form suitable for the input device with which the particular machine is

equipped. Often this means that it must be punched on paper tape like a teleprinter message; sometimes it must be punched on to cards.

In the modern high-speed machines the whole programme, or a considerable section of it, is taken into the machine before any of the operations are actually carried out. Since calculations performed on a high-speed machine always involve a great deal of repetition (as does the programme given above), this makes for faster operation than would be possible if the input tape or cards had to be read afresh each time a given set of operations were to be performed. Thus it will be seen that storage is required inside the machine for the programme as well as for the numbers used in the calculation. In most modern machines the same store is used for both purposes. This is made possible by the device of using a numerical code to represent the various operations to be carried out. For example, operation No. 2 in the above programme could be represented by the following number, 4,100,101,104. Here the first figure indicates that a division is to be performed—a multiplication, for example, might be represented by 3 and an addition by 1; the remaining figures stand for the numbers of the storage locations referred to. One consequence of representing the operations in a programme by numbers is that the operations may be altered by adding constants to the numbers which represent them. For example, if 1 is added to the above number, it will then stand for an operation which is similar to the previous one except that the result will be put in storage location 105 instead of 104. This technique of changing operations in a programme is used on a very extensive scale when writing programmes for a high-speed digital computer, and it enables the programme to be greatly compressed, thus saving space in the store. It is possible for the machine to add a new section to the programme by computing, according to rules provided, the numbers which stand for the operations concerned and then planting them in positions where they will form part of the programme. This is done only in a small way in practical computation, but it is important from the point of view of the present article since it means that there is no theoretical reason why a programme should not be written which, when once inside the machine, will modify and extend itself indefinitely. More will be said about this later.

PROGRAMMING A MACHINE TO LEARN

The action of a machine when performing a conditional operation depends, as was explained above, on the magnitude or sign of some number at that moment in the store. If the operations before the conditional operation are arranged so that the number in question depends wholly or partly on a number which has just been taken into the machine from the outside world through the input mechanism, the action of the machine may be made to depend on signals given to it. These signals can, moreover, bring about a gradual modification of the information held inside the machine so that action of the machine upon receiving any signal depends on the previous signals it has received and on the actions it has taken in response to them. It is on this principle that the so-called 'learning' programmes which are sometimes demonstrated on large automatic calculating machines are constructed. Some of these programmes can be very impressive in operation.

A particularly elaborate one which was constructed recently by A. G. Oettinger for the EDSAC, a large machine in the Cambridge University Mathematical Laboratory, enabled the operator to teach the machine to perform a conditioned reflex action. When the machine was working under the control of this programme, it was possible to apply a stimulus whose intensity could be chosen within certain limits. The machine responded by printing a symbol—either one of the figures between 0 and 7, or an X (which was interpreted as indicating that it could not make up its mind which figure to print). The operator could then express approval or disapproval, and could vary the degree of intensity of his approval or disapproval within certain limits; alternatively he could express unconcern. Suppose he decided that he would like to teach the machine to print a 3 every time it received a stimulus, even a small one. He would begin by giving the machine a sequence of medium stimuli and noting the responses. Whenever the machine printed a 3 he would express strong approval and whenever it printed some other figure he would express strong disapproval. After a time he would find that the machine would always print a 3, even if he reduced the stimulus to a low value. However, if he went on stimulating the machine lightly and expressed neither approval nor disapproval the machine would then gradually 'forget', that is, it would begin to print an occasional figure that was not a 3, and after a time would be printing just as many other figures as 3's. Various experiments could be tried and the behaviour of the machine compared with the typical behaviour of an animal in similar circumstances. For example, the effect could be tried of expressing disapproval occasionally during the teaching process, even though the machine had done the correct thing. It was also possible to destroy a conditioned reflex which had been formed and to replace it by another one.

The means by which this animal-like behaviour on the part of the machine is secured are very simple. Eight numbers are held inside the machine, one corresponding to each of the possible figures which can be printed. These numbers will be denoted by a_0 to a_7. When the machine is stimulated it selects the largest of these eight numbers, a_r say, and adds to it the number representing the strength of the stimulus. If the result exceeds a certain minimum value the figure corresponding to a_r is printed. Otherwise the machine prints an X. a_r is then increased or decreased according as the operator expresses approval or disapproval by an amount depending on the strength of that approval or disapproval. Finally a small random number, which may be positive or negative, is added to a_r. The number used is random only in the sense that it is obtained by a side calculation which is not linked in any way with the operations being carried out by the rest of the programme. The effect of adding a random number in this way each time a figure is printed is to give a certain irregularity to the behaviour of the machine. In order that the machine shall 'forget' if no approval is expressed, the eight numbers a_0 to a_7 are periodically multiplied by a constant slightly less than 1, so that if no approval is expressed they have a tendency to decay to zero. It will be

seen that the effect of expressing approval when a particular figure has been printed is to increase the chance of that figure being printed on subsequent occasions, and so, if done sufficient times, to give the appearance of a conditioned reflex action having been established.

GENERALISED LEARNING PROGRAMMES

The construction of a learning programme of the above type presents no difficulty to anyone who is familiar with the technique of programming. However, such a programme makes it possible to teach the machine only those things which the programmer had in mind when he wrote the programme. For example, the programme just described would not enable the operator to teach the machine to print different figures after alternate stimuli. If the programmer had wished to do so, he could have allowed for this possibility in his programme. In fact, at the expense of making the programme longer and more complicated, he could include any number of extra features, but obviously he could not think of every possible experiment which anyone might wish to try on the machine. All the programmer is doing, in fact, is to programme the action of the machine as it were at one remove; when he writes the programme he visualises, if not in complete detail, at any rate in general terms, all the possible actions which the machine can take in response to legitimate actions on the part of the operator. Such programmes are not, therefore, as interesting as at first sight might appear from the point of view of this article. What is wanted is a 'generalised' learning programme, which would enable an operator to teach the machine anything he chose, whether the idea of his doing so had occurred to the programmer or not. I believe that such a programme would not be a mere elaboration of the simple learning programmes which have been constructed up to date but would need to be based on some entirely new ideas. Presumably the programme would modify and extend itself as the learning process went on. As I have pointed out, existing machines contain the means for this extension; the difficulty is to construct a programme to make use of them. If such a programme could be made then it would be possible to teach the machine in much the same way as a child is taught.

Whether the new ideas I have referred to will be forthcoming, it is hard to say. Certainly, for the present, progress appears to be held up. Perhaps this will give comfort to those who cannot bear the idea of machines thinking; on the other hand it may stimulate others to further effort.

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NEW WEAPONS AND CIVIL DEFENCE

LEONARD BERTIN

During recent months the author, who is the Scientific Correspondent of the Daily Telegraph, *has had the opportunity of discussing the Civil Defence plans which have been developed to meet new weapons. This article is based on information he collected during talks with senior officials and scientists of the Home Office, and on visits to the Civil Defence Staff College for senior officers at Sunningdale Park and the Technical College for C.D. instructors at Falfield, Gloucestershire.*

While the atomic bomb represents by far the most serious new threat to Britain in any future war and Civil Defence authorities are rightly concentrating their greatest efforts on meeting it, the Home Secretary's recent announcement in the House of Commons (March 5) of the development and production of a new respirator is a reminder that the use of chemical weapons cannot be ruled out. There is no guarantee, either, that the bacteriological weapon, which has in the form of propaganda already found its way into the cold war, will not one day be employed in a hot one. Both the chemical and the bacteriological arms in fact are a far greater threat than they have ever been before.

The outstanding new factor in the field of chemical warfare, of course, is the group of so-called 'nerve gases'. These chemicals all have the property (which is shared to a lesser extent by insecticides like parathion) of irreversibly inhibiting the enzyme cholinesterase. This results in an accumulation of acetylcholine in both the central and peripheral nervous systems, and the development of classic symptoms of muscarine and nicotine poisoning. Pain in the eyes, difficulty in breathing, shock symptoms in the circulatory system, convulsions and curare-like paralysis ensue within a very short time. So rapidly do these nerve gases act that hapless people who are exposed to them must receive treatment, of which the chief is atrophine by injection, within about a minute, if it is to be effective. These so-called gases are all prepared as colourless, odourless liquids which readily evaporate. Their vapours can be inhaled or absorbed by mucous membrane in the eyes or gastro-intestinal tract. As liquid they can also be absorbed through the skin. Against their vapours, a well-fitting gas mask is a complete answer.

The nerve gases were first developed by the Germans and at the capitulation large stocks were found, both stored in bulk and loaded in projectiles. Britain has been slow to talk about them, but a study of the chemicals in Britain, Canada and the United States led Col. John Wood, chief of the medical division of the United States Army Chemical Centre at Maryland, to exclude specifically this group of gases from his assessment that no potential enemy would find it worth using chemical warfare methods against the Americas until it had established a bridgehead.

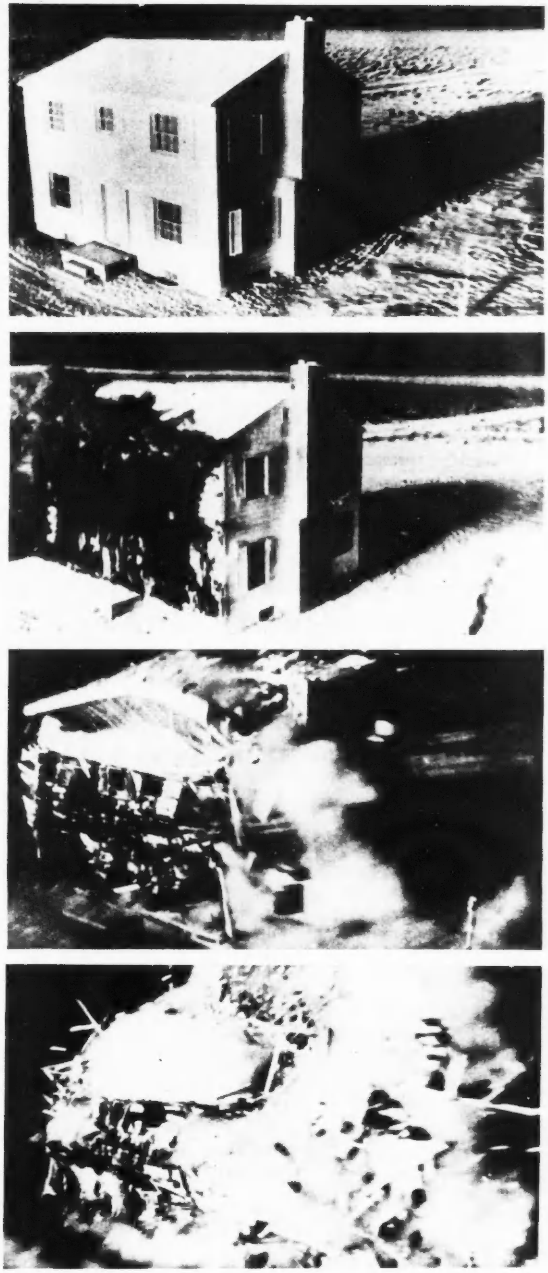
This was tantamount to classifying nerve gases as effective strategic weapons. British experts would not, I think, go as far as that. But, as a purely tactical weapon, there is no doubt that nerve gases must be seriously considered. The threat of their use will undoubtedly bring about the scrapping of all current respirator models so soon as there are others to replace them. That does not mean to say that the present ones (of which there are three principal models—the service, and heavy and light duty civilian types) are no use against the nerve gases. Provided the existing types of respirator are fitted well, they can protect the wearer against nerve gases. The latest civilian model, the first of the new series, however, incorporates an important modification which will certainly be copied in military models. This is a ring cushion in the form of a closed tube containing air at atmospheric pressure, which enables the mask to follow closely along its edge every contour of the face. The fact that the tube contains air and is at atmospheric pressure will undoubtedly make for long life.

Two factors have contributed to bring the bacteriological arm back into prominence. The first is the development of an effective means of distribution of small groups of bacilli, in aerosols so small that they will be subject to Brownian motion, which will serve to keep them floating about for long periods; the second factor is the discovery of means to secure even distribution of such aerosols over a wide area. But there is no reason to fear that some unknown and dread disease would suddenly be unleashed amongst us. The diseases we would need to fear are the 'old favourites', like anthrax, brucellosis, typhoid and plague.

Unlike bombs and war gases, germs, of course, are always with us in everyday life, and everyone in a civilised country, from the doctor to the small child, is used to fighting them. Modern standards of sanitation and cleanliness guarantee a measure of protection against an abnormal onslaught by disease-producing bacteria. But if atom bombs began to fall those standards could not be maintained, and then the bacteriological weapon would find most victims. And that brings us back to the atom bomb. . . .

Maj.-Gen. Stephen Irwin, chairman of Britain's Civil Defence Joint Planning Staff, summed up this weapon when he told me recently: "Atomic weapons have brought no new problems that cannot be dealt with by our scientists, firemen, wardens and doctors. It is only when the scale of the threat is multiplied many times, when there are more fires than our firemen can deal with, when more people are trapped than our wardens can reach and when medical services are swamped that things become critical." That is precisely what an atom bomb might do, especially if, as we fear, it were accompanied by a generous assortment of high explosive, anti-personnel and incendiary bombs. It is that sort of eventuality which our civil defence joint planning staff is trying to prepare for. It is something which Britain, with all its war-time experience, still knows little about, and it is reassuring to note a complete lack of dogmatic assurance in the approach of our planning staff to this new danger.

The atom bomb which burst over Hiroshima's twenty-six



In the Nevada atomic test on March 17, the effect on a number of buildings was studied. These pictures show what happened to one typical American wooden-frame house three-quarters of a mile from the explosion. Note that in the second picture one wall has been set on fire by the heat flash. The sustained pressure of the blast wave then proceeds to push the house backwards, blowing it to bits simultaneously; this effect is typical of *atomic* blast.

square miles on August 6, 1945, killed 80,000 and seriously injured the same number out of a total population of 320,000. About fifty buildings were left standing in the whole city. Perhaps the most terrifying feature of the raid was the firestorm which developed twenty minutes after the initial detonation. Winds of up to 40 m.p.h. were sucked in towards the blazing centre of the city from all directions, fanning this blazing holocaust to temperatures that would fuse iron. Hiroshima, of course, was in no way like a western city. The flimsy houses went down all too easily before the blast and the fire that followed. And to add to the casualties beyond measure, the population ignored or stood gazing at the bomber in the blue sky above, under the impression that it was a reconnaissance plane.

British assessments of what might be expected here are based on a well-instructed population receiving at least five minutes' warning, *and seeking cover*.

Assuming that the bomb were timed to burst at about 2000 feet above the ground, at which point it should achieve maximum effect, it is estimated that buildings in the average British city would suffer damage to a distance of from two to two and a half miles from the centre of devastation, and that within a radius of one mile 30,000 houses would be demolished or require demolition. A further 35,000 houses between one and one and a half miles would be rendered uninhabitable and require major repair.

That terrible picture is comparable in many respects with the worst saturation raids on Germany. But there is a difference, due to the peculiar effect of the pressure wave generated by atomic bombs. This takes the form of a fairly sustained pressure downwards and *outwards* from the point of explosion. The result is that buildings do not simply collapse, as in the case of conventional high explosive, but are 'pushed' over sideways in the direction away from the bomb.

This means that all roads except those directly radiating from ground zero are blocked by the debris of buildings. It means, in all probability, that an area from one to one and a half miles across will be reduced to heaps of rubble. Within that area, calculate the scientists, there might be upwards of 60,000 people killed or injured and needing treatment.

A far greater number may be buried in shelters without the slightest hope of extricating themselves without outside aid. Their plight and that of the wounded would be all the more serious because of the utter impossibility of rescue forces reaching them for some hours. It would be worsened by the fire hazard which, in the case of atomic bombing, is very serious.

Up to now we have made no mention of radiation. No doubt because it is new to us, this hazard has been given a great deal of prominence. A cold analysis of facts, however, has led Dr. E. T. Paris and his staff of scientists at the Home Office to relegate this risk to third place, after blast and fire. The position is summed up by saying that anyone near enough or exposed enough to get a lethal dose of radiation would probably be killed far more quickly by secondary effects of blast, such as falling masonry, or by primary or secondary fire effects. After an air burst, residual radioactive contamination is not expected to be serious.

More powerful bombs may in the future extend the area damaged by blast and fire but it is comforting to think that they will be powerless to extend much the lethal radius of initial radiations, since the present limiting factor of atmospheric absorption will still be effective and would be increased where there is mist, smoke or fog.

The fire risk, even if no supplementary high explosive and incendiary bombs were used, is considerable in atomic attack. With more powerful bombs, of course, the radius of fire damage would mount as the square root of the bomb's increased power, and not as the cube root as in the case of blast. But long-range fire hazards are more easy to guard against than radiation or blast. It has been found, as would be expected, that at some distance from ground zero* light-coloured curtains, especially those of wool, are far less likely to be ignited than dark ones, especially if the latter are made of cotton or rayon. Both could be effectively protected by whitewashing the window panes (since blast waves, travelling at the speed of sound, will reach them long after heat radiation travelling at the speed of light).

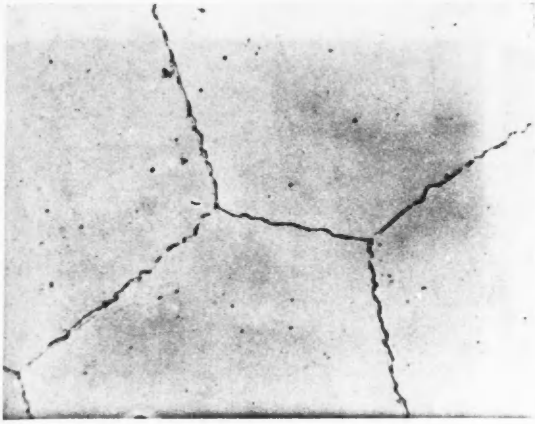
This fire problem is by far the most urgent one, to be dealt with after an incident, because of its power to magnify damage already done and increase the number of casualties. Furthermore, with fire spreading rapidly, the situation could soon get out of control. (It should be remembered that the situation would be aggravated by the strong winds created by the central conflagration, as happened in Hiroshima.)

This area is the area of self-help. In it much that happens will inevitably depend on the training in basic fire-fighting, rescue and first aid which all individuals will have received beforehand. It will depend on mothers knowing how to deal with dangerous wounds, and men knowing enough of the difficult art of extricating persons from wreckage, to save neighbours without adding to their injuries. It is a field of training which none of us can afford to neglect.

The second degree of help, from immediate outside areas, supplemented by completely self-sufficient mobile columns, cannot be expected to materialise for some time. Its efficient deployment will depend on a great deal of further research, on planning and a high level of organisational training, including the use of wireless. Many services will be involved. In addition to fire brigades, damage control, rescue, ambulance services and police, communications, water, gas and electricity, there will need to be welfare services like the W.V.S. and emergency feeding units. Controllers will need to maintain the steady flow of these services along roads cluttered up, possibly with refugees. Nearer the centre they will need to limit drastically the forces that are committed in order that the best use can be made of all roads that are unblocked by debris. For this a high degree of staff work is necessary.

Those who think that planning against such eventualities is premature, should be reminded that Britain is in a very vulnerable position and that her present air defences could not hope to bring down more than a small fraction of a well-trained, properly equipped and determined raiding force. In such a position it is vital to show that Britain is not a factor for peace that can be assessed coldly in terms of twenty or thirty atom bombs.

* The ground point immediately below the bomb burst.



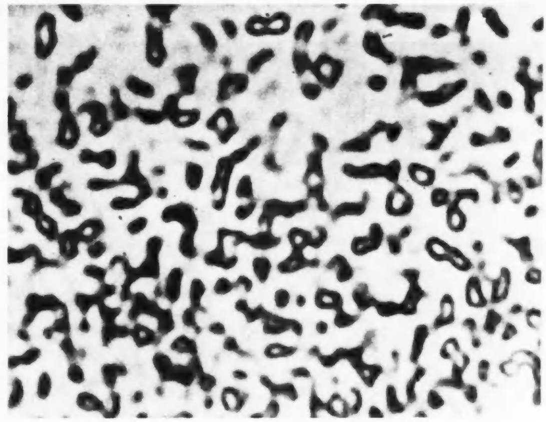


FIG. 1 (*left*). Duralumin, as quenched from 450° C, shows in this photomicrograph no structure except the boundaries between its crystals—this is typical of the appearance of pure metals and 'solid solutions'. During the first stages of 'age hardening' no visible change in structure takes place, but the alloy gains in strength and hardness. (Magnification, × 4000 approx.) FIG. 2 (*right*). The final stage in the age-hardening process of Duralumin is the precipitation of a copper-aluminium compound ($CuAl_2$), which appears as 'globules' in this photomicrograph; the alloy has now lost its peak properties, and is soft and weak.

METALS AND MODERN AIRCRAFT

J. GORDON PARR

B.Sc.

Forty years ago aircraft travelled at speeds below 100 m.p.h. Today speeds of over 600 m.p.h. have been attained. Yet the very fast modern machines are more reliable and safer than the machines of forty years ago, and indeed their safety is no more conjectural than that of a motor-car. The achievement of such a vastly improved performance is largely due to revolutionary advances in engine design, and to the development of airframes capable of withstanding the severe strains imposed upon them by movement at high velocity.

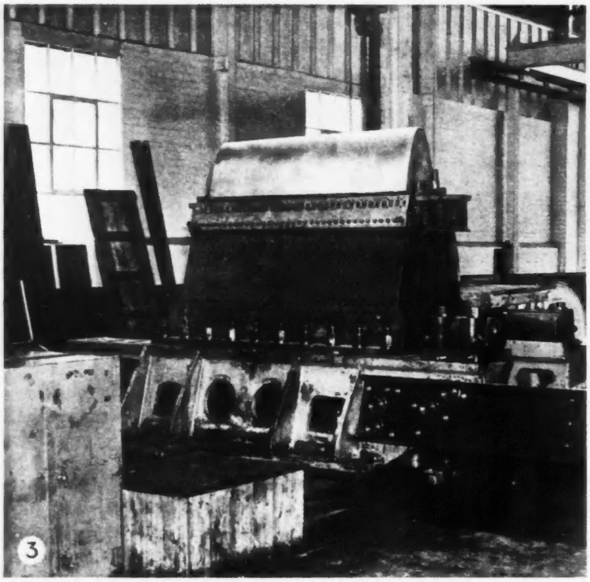
The bodywork of high-speed aircraft must be more than just strong; it must also be 'clean' aerodynamically: this means that it must be free from projections and it must have a smooth surface to minimise its air-resistance, or 'drag'. The elimination of struts and other supports, a change which accounts for the obvious external difference between the old and the new planes, demands additional strength in the wing and in its connexion to the fuselage. Consequently the evolutionary trend in aircraft design which has brought cleaner lines and higher speeds has demanded an intensification of the search for constructional materials combining lightness with greater strength. Aeronautical progress has thus been inseparable from advances in particular branches of metallurgy.

The most spectacular single contribution of the metallurgist in the aircraft field was made towards the end of the 1914–18 war. This was the introduction of the alloy Duralumin. The aeroplanes of that war were made largely of wood, a 'dash' of mild steel being added to increase their strength; but with the advent of Duralumin, development of the all-metal plane began.

The property which makes Duralumin and similar alloys so useful is their ability to 'age-harden'. Even today the precise mechanism of the age-hardening process cannot be agreed upon, though it is possible to give a generally accepted working picture of the behaviour of age-hardening alloys.

The early Duralumin alloys were, basically, 4% copper and 96% aluminium. If this alloy is heated to temperatures around 450° C (it is quite solid up to 650° C) the copper is in 'solid solution' with aluminium. That is, in the regular arrangement of aluminium atoms, three atoms haphazardly chosen out of every 200 are replaced by copper atoms.

Now, just as more sugar can be dissolved in hot water than in cold, so can more copper atoms replace aluminium atoms in a hot solid solution than in a cold one. And, continuing the analogy, when a hot solution of sugar in water is cooled, sugar is precipitated; and in the same way copper is precipitated from a cooled aluminium-copper alloy. But, in this case, the copper precipitates not as the elementary metal but as the copper-aluminium compound, $CuAl_2$. The precipitation process does not take place immediately, however, and if the Duralumin in the solid solution phase is quenched in water, or rapidly air-cooled from a temperature of 450° C, the atoms remain in solid solution for some days. The mechanical properties of the solid solution are very similar to those of pure aluminium; the alloy is soft, ductile and can be rolled or pressed into shape. Eventually, however, the copper precipitates as copper-aluminium compound. This is preceded by diffusion of copper atoms and their aggregation together. Only when aggregations of copper atoms have formed does combination of copper atoms with aluminium atoms occur,



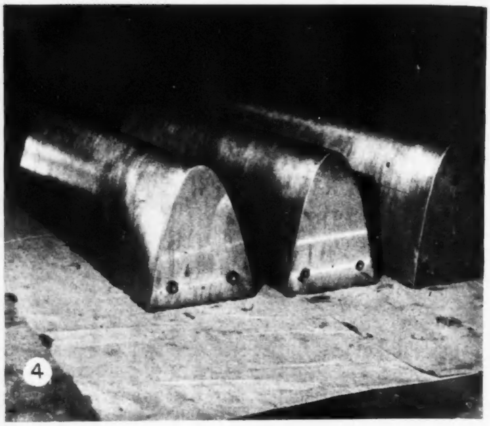


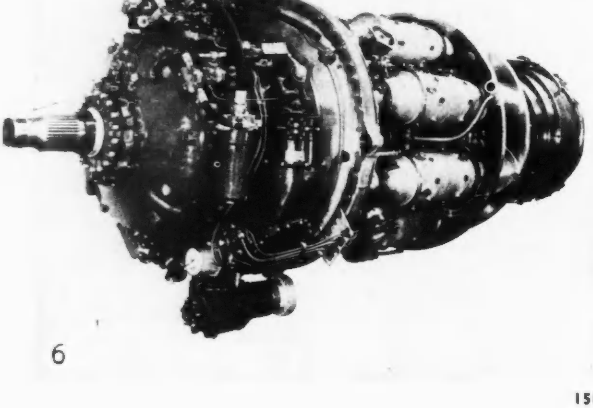
FIG. 3. Stretch-pressing a section of the leading edge of the 'Comet' wing.

FIG. 4. Formers used in the stretch-pressing process. (*Courtesy, de Havilland Aircraft Co. Ltd.*)

FIG. 5. A group of aluminium alloy castings used in the de Havilland 'Dove' aircraft. (*Courtesy, Northern Aluminium Co. Ltd.*)

FIG. 6. The era of jets and turbo-prop engines—epitomised by this Proteus MK 705 propeller turbine—brought new metallurgical problems. (*Courtesy, Bristol Aeroplane Co. Ltd.*)

FIG. 7. The stages in making a turbine blade. The preliminary forging operations produce a roughly shaped blade from a cylindrical block. The forged blade is then machined to exact size and contours (see Fig. 8). (*Courtesy, Henry Wiggin & Co. Ltd., and de Havilland Aircraft Co. Ltd.*)



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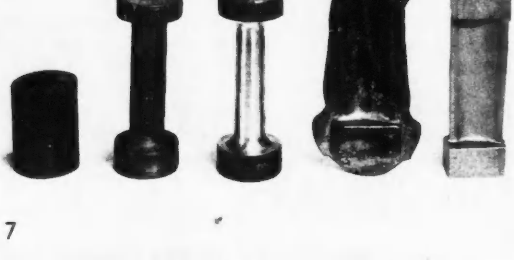

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followed by precipitation of $CuAl_2$. The aggregation of copper atoms causes an increase in the hardness and strength of the alloy. If the alloy is to be useful, the actual precipitation of copper-aluminium compound has to be prevented, for this stage is accompanied with a decrease of strength and of hardness.

Atoms in metals are arranged in a pattern of parallel planes, and when the metal is deformed by stretching or compressing or bending, layers of atoms slide over each other like cards in a pack. It is believed that small irregularities in the layers of atoms lock the layers together and make the sliding process more difficult—just as irregularities on the surface of cards in a pack stopping the cards slipping over each other. The aggregates of copper atoms in Duralumin behave as 'locks'; they obstruct the sliding motion of the atom layers, and the metal is less easily deformed. In other words, it is stronger.

Unfortunately, this part of the ageing process cannot be seen under the microscope, and the presence of copper aggregates and their behaviour can only be deduced from indirect evidence. In fact the first change involved in the process of age-hardening seen through the microscope is the precipitation of the compound $CuAl_2$—which does not 'lock' the atom layers. (Figs. 1 and 2.)

The age-hardening process has to be checked by quenching at a stage when the alloy is still soft, and can be shaped. The ageing process that occurs afterwards must not be allowed to proceed to the final stage of precipitation. On the face of it, this seems to be an impossible demand, but the onset of this precipitation can be inhibited, or at least delayed considerably, by adding other metals. Research has produced Duralumin alloys which contain silicon, manganese and magnesium whose breaking load is 25-30 tons per square inch. That is, they have the same strength as mild steel but only one-third of its weight.

CREEP

Unfortunately, if the temperature is raised much above atmospheric the strength of the light alloys is seriously reduced. This shortcoming is particularly noticeable if the alloy is continuously stressed, for under these circumstances it 'creeps'. Creep is the phenomenon of a metal stretching plastically—like a piece of Plasticine—when it is pulled for a long period of time. Normally, one considers that a metal has a certain definite strength. That is, a bar will break when it is pulled with a force of x tons. But if a load of less than x is applied for a long time the metal will slowly stretch and finally break. Creep is most pronounced in metals above their elastic limit; and because elasticity decreases as the temperature is raised, metals creep more as they are heated. Compared with steel, Duralumin is much less elastic. At, say, 75 C under a steady load of 15 tons per square inch applied for a week, mild steel would regain its original length when the load was released; but Duralumin would show a definite and permanent extension.

For these reasons, the Duralumin type of alloy cannot be used at temperatures much above atmospheric; moreover, if the temperature is raised to 150 C or above, complete precipitation of $CuAl_2$ occurs, with a consequent decrease in strength.

CORROSION

Duralumin alloys are particularly prone to corrosion, especially in sea-water. The dangers are more than just an eventual weakening of the structure; the roughening of surfaces causes additional 'drag', and, worse, a corrosion crack may be the nucleus of a fatigue failure—of which more will be said later. Further, if a component is stressed (i.e. is pulled or twisted)—and most parts of an airframe *are* stressed—it is much more likely to corrode. Corrosion usually takes place between the grains, or crystals, of which metal is composed, beginning at the surface and gnawing its way down into the metal. One way of combating corrosion is to 'clad' the strong basic metal with a corrosion-resistant light metal—pure aluminium is particularly suitable. A slab of Duralumin is cleaned, sandwiched between two sheets of pure aluminium, heated to 450 C and rolled to make a good union between alloy and pure metal. A very thin coating is adequate, and the strength to weight ratio of the article is not very much reduced.

The metal skin of an aircraft, which contributes largely to the strength of the airframe, is made in this way. The sheet used for so important a purpose must be strong, stiff and very accurately shaped. To help achieve these properties, the sheet is nowadays 'stretch-pressed'. The name describes the process: the sheet is pulled into shape over a former and it is stretched by about 10%. (Figs. 3 and 4.)

FATIGUE

Readers will remember Nevil Shute's novel, *No Highway*, in which the central character was a scientist who predicted, to the alarm of everyone but himself, a new kind of fatigue trouble that could cause the fracture of aeroplane tailplanes. As was to be expected from a novelist who has had considerable experience as an aircraft designer, the plot was based on more than a mere modicum of fact, and because of this the book brought home to a very large number of people the very real risks of fatigue fracture. A metal breaks under a repeated load more readily than a single static test would indicate; and the horrid outcome of such perversity may be easily imagined. As a precaution the engineer introduces a 'safety factor', using his material so that it is subjected to only a portion of the load which an ordinary static test warrants.

Fatigue fractures of metals have clear-cut features and are easily distinguished from that kind of breakage which occurs when a metal is simply overloaded instantaneously. A fracture due to rapid overloading is rough and crystalline; but a fatigue failure is smooth and often marked with concentric lines. It usually starts at a minute surface crack and spreads across the component at a rate which depends on the load, the fluctuations of load, and the nature of the metal. Thus the amount of metal which is left to take the load is progressively reduced as the fatigue fracture spreads across. The last stage—a sudden snap—is simply due to overloading, brought about because the size of the component giving active support has been reduced by the spread of the fatigue fracture. The greatest strain is often put on components—particularly engine components—when a machine is started, and it is then that final fracture takes place.

TABLE I

Compositions of some heat-resistant alloys

	Carbon	*Nickel*	*Chromium*	*Molybdenum*	*Silicon*	*Manganese*	*Cobalt*	*Tungsten*	*Titanium*	*Aluminium*	*Iron*
Nimonic 80A:	0·05	77·0	20·0	—	—	—	2·0 max.	—	2·5	0·5/1·8	—
Nimonic 90:	0·10 max.	Remainder	18·0/21·0	—	—	—	15·0/21·0	—	1·8/2·7	0·8/1·8	—
Hayes stellite 27:	0·40	36·0	26·0	6·0	0·4	0·5	30·0	—	—	—	1·0
Hayes stellite 23:	0·40	2·0	25·0	—	0·6	0·3	65·0	6·0	—	—	1·0

The slightest irregularity may act as a nucleus for fatigue failure—a mark left on the metal surface by the machinist, a crack produced during heat-treatment, a small groove caused by wear at a bearing. If the metal is susceptible to corrosion, the tendency to fatigue failure is far greater, for surface irregularities are more numerous.

The most effective weapon against fatigue failure is watchfulness. And, because fracture is initiated at small cracks and irregularities, the careful examination of components before use and during overhaul is vital. Small cracks cannot be seen by the naked eye, and so a variety of ingenious methods of crack-detection have been developed. These methods are in regular use, and although they are non-destructive they are usually cumbersome. For example, in one method the component is immersed in a bath of fluorescent solution and then its surface is thoroughly dried. Any cracks hold a little solution which glows under ultra-violet light, and the crack is easily spotted. Another technique, applicable only to magnetic materials, involves magnetising the component, and dusting it with iron powder. The particles collect around the cracks. Perhaps the oldest method of crack-detection is to hit the component and listen to its ring—an unreliable china-shop technique. Then there is the ultrasonic method in which the reflection or transmission of sound-waves through a metal is measured. Transmitter and receiver are passed along the component and impulses are received and recorded on a cathode-ray oscillograph. Cracks or holes are detectable because they reflect or absorb the sound-waves, and produce a deviation from the normal transmission through good metal. (This, incidentally, is one of the few methods that can locate internal cracks.)

MAGNESIUM ALLOYS

The use of magnesium alloys in airframes is, in this country, mainly limited to castings and undercarriage parts. Champions of magnesium are disappointed at this country's preference for aluminium alloys, but the magnesium clientele is growing; and one notable instance where aluminium has been completely ousted is in landing wheels. The production of magnesium articles bristles with metallurgical problems. The magnesium alloys tend to catch fire when they are cast—sometimes, even, while they are being machined. In the past, manufacturing difficulties led to variations in mechanical properties, and the alloys often cracked when they were rolled hot into sheets. But today, largely as a result of the addition of zirconium, this obstacle has been overcome; these alloys can be forged and rolled, and they possess a happy (and reliable) combination of strength and toughness. (The remarkable improvement in the mechanical properties of magnesium alloys which is brought about by the addition of a small proportion of zirconium, e.g. 1% or less, has been intensively investigated: reasons for the improvement are discussed in *Progress in Metal Physics No. 2* (1950), p. 134 *et seq.*)

THE 'NEW' METAL, TITANIUM

Until quite recently, no one really considered the necessity of using any metals other than aluminium and magnesium for aircraft manufacture. Reviewing the situation today, it is quite clear that titanium alloys in aircraft structures are a distinct possibility—they are strong and corrosion-resistant. But titanium is expensive to extract from its minerals, and its high melting point (1800° C) makes melting and casting difficult and costly.* At present it costs thirty times as much to produce as aluminium. But, unlike aluminium alloys, which do not retain their strength above atmospheric temperature, titanium alloys have a favourable strength-to-weight ratio up to 300° C. If airframe components of the future demand such properties, then titanium may come in.

THE GAS-TURBINE AND JET ENGINES

The introduction of the gas-turbine to aeronautics caused a complete breakaway from the general trends

* See article "Titanium", DISCOVERY, April 1953.

of metallurgical development in engine materials, and demanded new alloys capable of withstanding high temperature and stress.

The principle of the gas-turbine is that a fired mixture of fuel and air, instead of working a piston, propels the blades of a turbine rotor. This may be applied in one of two ways to aircraft propulsion. The turbine may be directly coupled to an airscrew—the turbo-prop engine. Or, as in the jet engine, the turbine's purpose is only to drive a compressor which draws air into the firing chamber. The fuel and air mixture is ignited, expands vigorously and is expelled from a jet, actuating the turbine en route. The reaction against this forceful stream propels the aircraft.

Turbo-prop and jet offer the same problems to the metallurgist, for the efficiency of both depends upon a high temperature of operation. Therefore, combustion chamber and turbine have to be made of a material that will withstand at least 600 C (at lower temperatures the engine is not efficient); and today the operating temperature may be as high as 950 C.

CREEP OF TURBINE BLADES

Conditions are most severe in the turbine rotors, for, revolving at about 15,000 r.p.m. they are subjected to considerable centrifugal stress, which at high temperature leads to creep.

Creep in steels and in the metals used for jet blades and rotors is not nearly so accentuated as in the light alloys. But in the jet, very high temperatures are attained; and at these temperatures and under the accompanying stress, the metal creeps in just the same way as Duralumin does under much less severe circumstances. Therefore the metallurgist is faced with this problem: he has to produce a metal which, at a given temperature and subjected to a given pull (corresponding to the centrifugal stress of the turbine), can be relied upon to have a certain length of life. This life may be short, for the criterion that determines the limit of usefulness may not be fracture, but the extent to which the metal may stretch before the turbine blades foul their casing.

There are other problems, too, but this is the biggest one. The parts of the turbine most critically affected are the blades on the rotor wheel, against which the hot gases impinge. Alloys containing much iron are not adequate at temperatures higher than 650 C, so cobalt-base and nickel-base alloys are generally used. Nickel and cobalt are silver-white metals, soft when pure, and about as heavy as iron. The Nimonic series of alloys based on nickel has grown alongside the jet, being improved as conditions have become more exacting. Table I shows how complex jet-blade alloys have become. (Figs. 6–8.)

A detailed analysis of the reasons for the satisfactory performance of these alloys is almost impossible, because of their complexity. The nagging insistence of the engineer for better materials has been responsible for hit-and-miss tactics, and the metallurgist has produced alloys which behave satisfactorily though he may not be able to offer any theoretical explanation why a particular alloy has its desirable properties.

FIG. 8. A nickel alloy turbine blade. Note that the 'root' of the blade is of 'fir-tree' section which ensures a secure joint between blade and rotor disc. (*Courtesy, Rolls-Royce Ltd.*)

MOLYBDENUM AND CORROSION AT HIGH TEMPERATURES

Bearing in mind the complexity of contemporary jet alloys it is ironic that a pure metal—molybdenum—has creep-resisting properties as favourable as the most complicated alloy. The possibility of molybdenum alloys is being investigated at present, but two big obstacles stand in the way: there is the difficulty of making an alloy of a metal whose melting-point is 2600 C (nearly twice as high as the melting-point of nickel), and there is also the fact that molybdenum and its alloys are corroded by the hot gases generated in the turbine engine.

Up to the present, the corrosion-resistance of alloys has been of secondary importance, for contemporary alloys fail by creep rather than by corrosion. But the corrosion specialist can no longer sit back, for the particular problem of molybdenum needs solving.

The search for metals which will withstand the severities of high-temperature service is not easy, nor is it completed. Add to its obstacles the more conventional difficulties of fatigue failure in turbine components and the snags that arise in making bearings, casings, shrouds and all the other parts of the aero-engine, and one wonders how the metallurgist has kept up with the ever-increasing demands of the engineer. As to the future—the extravagancies that are expected in first efforts will have to be sobered down to an economic level that can be maintained. This may bring about a demand for metals whose production costs can be cut if production is increased; it will, on the other hand, preclude the use of metals which are inevitably expensive. Consequently, alloys must be devised whose major constituents are cheap, and future developments will more than before have the housewifely aim of cutting costs.

Far and Near

Night Sky in May

The Moon.—New moon occurs on May 13d 05h 06m, U.T., and full moon on May 28d 17h 03m. The following conjunctions with the moon take place.

May					
10d 19h	Venus in conjunction with the moon		Venus	4°	S.
14d 11h	Mars	,,	Mars	4°	S.
25d 09h	Saturn	,,	Saturn	8°	N.

The Planets.—Mercury is a morning star, rising at 4h 14m and 4h on May 1 and 15, respectively, and after superior conjunction on May 24 it becomes an evening star; at the end of the month it sets at 20h 50m, about three-quarters of an hour after sunset, and is too close to the sun for favourable observation. Venus is a morning star, rising at 3h 30m, 2h 55m and 2h 20m on May 1, 15 and 31, respectively. Its stellar magnitude averages about −4·2 and the visible portion of the illuminated disk varies from 0·1 to 0·36 during the month. Mars sets at about 21h throughout May and is visible in the western sky after sunset, but at the end of the month it sets less than an hour after the sun and will not be so easy to observe. Jupiter sets at 20h 50m and 20h 15m on May 1 and 15, respectively, and is in conjunction with the sun on May 25, after which it becomes a morning star but is too close to the sun to be seen during the latter portion of the month. Saturn rises at 17h 20m, 16h 20m and 15h 15m at the beginning, middle and end of the month, respectively, and is visible until the early morning hours. Its stellar magnitude during May averages about 0·6 and it can be easily recognised by its proximity to Spica of which it is about 5° N. on May 24.

The meteor showers known as the η Aquarids are active in the early portion of May but are not visible until the early morning hours. For many years it has been believed that the meteors are associated with Halley's Comet of which they were supposed to be the debris, but recent work at Jodrell Bank carried out by Prof. A. C. D. Lovell and his team has thrown some doubt on this connexion, though it cannot yet be said definitely that the connexion has been disproved. The velocities of these meteors, as determined at Jodrell Bank, were less than would have been expected from the debris of Halley's Comet, but more work will be carried out and the results carefully examined before a final pronouncement is made on the matter.

It may be mentioned that the Orionid shower about the middle of October was also believed to be due to the debris of Halley's Comet, in this case the encounter taking place at the ascending node, just as it was supposed to take place at the descending node in May. The work at Jodrell Bank, however, has thrown some doubt on this connexion also.

A Cobalt-60 'Bomb' for Mount Vernon Hospital

Soon after the war it became evident that Cobalt-60 was the most satisfactory substitute for radium that could be provided. It was suggested by Dr. A. J. Cipriani and Prof. W. V. Mayneord that this isotope could find use in cancer therapy. It is prepared by irradiating ordinary cobalt metal in the high neutron flux produced in heavy water piles, such as the NRX pile described in the last issue (pp. 105–6) of DISCOVERY. Canada has three units for treating cancer patients in which a cobalt-60 'bomb' replaces the conventional radium source. These are located in London (Ontario), Saskatoon and Vancouver. Now a Canadian philanthropist, J. W. McConnell, has presented a cobalt-60 unit of revolutionary design to the British Empire Cancer Campaign. The machine, which will be installed in the Mount Vernon Hospital, Northwood, is nearly 200 times more powerful than radium units in current use. The cobalt-60 unit (rated at 1100 curies) is equivalent to 1500 grams of radium. Its beam of radiation has the penetrating power of an X-ray machine working at 3 million volts. Over 50% of the dose delivered on the skin will be received at a depth of 10 centimetres within the tissue. It is therefore particularly suited for irradiating deep-seated cancers.

The cobalt-60 loses half its power in 5·3 years. This does not present any real difficulty as the cobalt can be reactivated in a nuclear reactor: this would be done after the unit has been in use for about three years.

Expert Committee to Investigate the Sea Floods

Scientific and engineering experts are included among the members of the committee set up by the Government to inquire into the February floods. The committee's terms of reference are as follows:

To examine the cause of the recent floods and the possibilities of a recurrence in Great Britain; to consider what margin of safety for sea defences would be reasonable and practicable having regard to the estimated risks involved and the cost of protective measures; to consider whether any further measures should be taken by a system of warning or otherwise to lessen the risk of loss of life and serious damage to property; and to review the lessons to be learned from the disaster, and the administrative and financial responsibilities of the various bodies concerned in providing and maintaining the sea defences and restoring them in the event of damage; and to make recommendations.

Chairman of the committee is Lord Waverley, the other members include:

Sir Donald Fergusson, former Permanent Secretary, Ministries of Fuel and Power, and Agriculture and Fisheries;

Sir Claude Inglis, Director, Hydraulics Research Station, Department of Scientific and Industrial Research;

Mr. R. G. Leach, formerly Deputy Financial Secretary, Ministry of Food;

Sir Basil Neven-Spence, Lord Lieutenant, County of Zetland;

Prof. J. Proudman, Professor of Oceanography, Liverpool University;

Mr. A. S. Quartermaine, President, Institution of Civil Engineers;

Lord de Ramsay, Lord Lieutenant of Huntingdonshire;

Prof. J. A. Steers, Professor of Geography, Cambridge University;

Sir John Wrigley, former Joint Deputy Secretary, Ministry of Housing and Local Government; and

Mr. T. Yates, General Secretary, National Union of Seamen.

Pocket Calculating Machine for Laboratories

The Curta Calculating Machine, which recently came on the British market following its first appearance in Switzerland in 1949, is rapidly gaining favour in scientific circles. Several thousands of these machines are now in use in Britain, and about a third of these have gone to scientific establishments, including Government laboratories, industrial research units and industrial research associations, and university laboratories. The amount of statistical work which is today inseparable from medical and agricultural research has also led to their widespread use by scientists working in these fields.

The machines are so compact, that they can be carried in one's pocket or brief-case. The Model I Curta has a diameter of $2\frac{1}{16}$ in., a height of $3\frac{3}{8}$ in. and weighs 8 ounces. The Model II measures $2\frac{9}{16}$ $3\frac{7}{8}$ in. and weighs 12 ounces. They are almost silent in operation, while another advantage to be considered in connexion with their use in laboratories derives from the fact that the materials of which their component parts are fabricated are practically non-corrosive, being anodised aluminium, nickel-chrome steel and brass.

There are two models of the Curta. Model I has a capacity of eight figures in the setting dials with six figures in the counter register and eleven figures in the product register. Model II has a capacity of eleven by eight by fifteen. Each register has visible dials and the machines are equipped with tens transmission throughout both the product and counter registers. This enables short cuts to be made both in multiplication and division.

The machines, in particular the Model II, are excellent for statistical work; for example, they make it possible to carry out rapidly and accurately such procedures as those involved in the calculation of standard deviations—the accumulation of

squares, accumulation of observations and the finding of square roots.

The fact that the machine is small enough to hold in the hand is a great convenience where computations require reference to tables of logarithms, etc. In such cases it is possible to work with the machine held above the tables which can then be constantly consulted without any need for the operator to shift even his head. To facilitate the computation of square and cube roots, etc., special tables are available.

Harwell Isotope School's Extra Course

The Isotope School at Harwell is holding an additional course this year—July 6-13. Applications to be considered for this course should be sent to the Isotope School, A.E.R.E., Harwell, Berkshire, not later than June 8, 1953. The fee is £40, plus 7 guineas a week for accommodation in the hostel.

The Early Days of Synthetic Dyestuffs

In the article "O. N. Witt: Father of Colour Chemistry" (DISCOVERY, March 1953, p. 99) it was mentioned that the firm of Williams, Thomas and Dowever with which Witt was associated was the precursor of Williams (Hounslow) Ltd. We have since received a copy of the history of this dyestuffs firm entitled "Seventy Five Years of Progress", which is particularly interesting for the information it gives about the early days of dyestuff manufacture at Brentford and Hounslow, and the references to the pioneer work of Greville Williams and his sons, and Prof. Arthur G. Green.

Catalogue of Electrical, Radio and Electronic Books

The latest booklet in the series of scientific and technical catalogues issued by H. K. Lewis & Co. Ltd. (of Gower St., London, W.C.1) covers books dealing with electrical engineering, radio and electronics, and contains 27 pages.

Schools Fail to Attract Science Graduates

The shortage of graduate science masters in schools has been mentioned many times in DISCOVERY, and the latest figures issued by the Appointments Board of Oxford University indicate that this situation is unlikely to be corrected soon. 482 science students obtained honours degrees last year, but only 71 showed any interest in teaching posts, and half of these were interested solely in university lecturing or research posts. In fact, only 17 took teaching posts in schools, and all these were in public schools. Industry, however, took 105 of the 482 science graduates.

Correction

The caption to Fig. 4 in last month's article "Titanium" (p. 110) should read: "Line diagram of melting furnace."

THE BOOKSHELF

Evolution in Action *by Julian Huxley (London, Chatto & Windus, 1953, 160 pp., 9s. 6d.)*

Dr. Julian Huxley's latest book can be regarded from certain points of view as the best that he has ever written. The wealth of detail to be found in his earlier *Evolution, the Modern Synthesis* (1942) has been gestated; material about more recent work has been added, and the result is a thoughtful and well-rounded essay. Although there is no lack of illustrative detail, yet the overwhelming impression given to the reader is one of authoritative exposition of a type more usually expected from the philosopher than from the biologist.

Too often the biologist seems to be at the mercy of an excess of detailed facts that spoil the unity of his 'choreography'; or else he conveys the broad sweep of an overwhelming idea, but without the development in detail of particular points which is necessary to substantiate that idea.

Here the biologist knows the details—no one could doubt it—and commands their appearance at precisely the right moment and for the right length of time to give the 'feeling of unity and sweep' of the process of evolution which, as Dr. Huxley says, he is seeking to communicate.

This is important because in his last three chapters Huxley takes the story forward into the realms of the human mind, which, he says, makes man the master of his own evolution. The hesitation so evident in the final chapter of his *Evolution, the Modern Synthesis* with its brief reference to the function of 'tradition' as a sort of mental germ plasm and its brief statement that "human progress consists of increases in aesthetics, intellectual and spiritual experience and satisfaction" has been replaced by a greater sureness of direction.

Man's future progress lies indeed with eugenics and the breeding of a better stock; even more so, it will depend on the greater exploration and understanding of man's inner life, the greater development of his spiritual nature.

Huxley uses the term "Evolutionary Humanism" to describe his godless religion, which he sees as "the overall relation between man and his destiny, and one involving his deepest feelings, including his sense of what is sacred". He feels that here, in the appreciation of man's mental, linguistic and finally spiritual evolution, there should lie "the germ of a new religion, not necessarily supplanting existing religions but supplementing them".

How man can scientifically study the truths of mystic introspection seems likely to remain for many years a major problem, easier to mention than to solve, for mysticism communicates by belief and inspiration, not by logic and close-knit reasonings.

DEREK WRAGGE MORLEY

Augustine to Galileo: the History of Science A.D. 400-1650 by A. C. Crombie *(London, Falcon Education Books, 1952, 436 pp., 42s.)*

The men of the 16th and 17th centuries, conscious of the remarkable revolution in science going on in their own time, and harassed by the die-hards of the scholastic tradition, came to see the Middle Ages as one long era of scientific inertia and obscurantism. That view prevailed until quite recently. However, from the beginning of this century men like Duhem have shown that medieval science did have its achievements, and that even some discoveries, attitudes and methods formerly believed to be essentially modern were really derived from medieval sources.

We can therefore be grateful to Dr. Crombie for providing us with the first comprehensive survey of medieval science in the English language. His knowledge of the subject is wide, and he has distilled into some four hundred pages the essence of what the reader might spend several years acquiring from the existing literature. Furthermore, Crombie achieves a balance between the physical and biological sciences which is exceedingly rare in books on the history of science.

The Dark Ages up to the 12th century are given only a summary treatment as a prelude to what follows. Then comes a chapter on the reception of Greco-Arabic science in the West (chiefly 12th and early 13th centuries). The bulk of the book is devoted to the 13th and early 14th centuries—correctly so, for it is in this period that medieval science was most truly creative. But it is unsatisfactory to jump from this point to the Scientific Revolution of the 16th and 17th centuries, if one gives only a few brief and often casual references to the transmission of thought from one to the other.

In fact, the intervening period is one in which the incipient break-up of feudal society brought a conservative reaction of authority-worship that well-nigh put an end to the creative movement and drove even the literary transmission of its achievements into a position something like that of an underground movement. If the object of the book had been simply to describe the best scientific thought of the Middle Ages it might justifiably have stopped about 1350. But Crombie's main thesis is that most of the ideas (not quite all, he admits in page 275) that went to make the Scientific Revolution were actually derived from the work of 13th- and 14th-century scholars. Now it is perfectly true that many lines of thought in this earlier period read like the first steps towards those which revolutionised science around 1600. But there are so many uncertainties about the transmission that it is no simple matter to decide how much the Moderns derived from the High Medievals and how much they created independently for themselves. A most

Continued on p. 165

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OFFICIAL APPOINTMENTS

ASSISTANTS (SCIENTIFIC): The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to December 31, 1953, but an earlier closing date may be announced either for the competition as a whole or in one or more subjects.

Age at least 17½ and under 26 years of age on January 1, 1953, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted.

Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects:

(i) Engineering and physical sciences.
(ii) Chemistry, bio-chemistry and metallurgy.
(iii) Biological sciences.
(iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing).

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Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1., quoting No. S.59/53. Application forms should be returned as soon as possible.

SENIOR EXPERIMENTAL AND EXPERIMENTAL OFFICERS required by DIVISION OF ATOMIC ENERGY (PRODUCTION) at Sellafield, Cumberland; Salwick, near Preston; and Culcheth, near Warrington for work in the following fields: Chemistry, Physics, Metallurgy, Welding, or Research Planning. Qualifications: over 35 (for SEO), and 26 (for EO), with at least Higher School Certificate in Science subjects, and good experience in one of the fields mentioned. Salary ranges £803–£1033 and £597–£754. Houses within reasonable time, if married. Further particulars and application forms from Ministry of Supply, D.At.En.(P.), Risley, Warrington, quoting 447.

EXPERIMENTAL OFFICERS AND ASSISTANT EXPERIMENTAL OFFICERS in various Government Departments. The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31st December, 1953, but an earlier closing date may be announced either for the competition as a whole or in one or more subjects. Interviews will generally be held shortly after the receipt of the completed application form.

The posts are divided between following main groups and subjects: (*a*) Mathematical and Physical Sciences, (*b*) Chemistry and Metallurgy, (*c*) Biological Sciences, (*d*) Engineering subjects and (*e*) Miscellaneous (including e.g. Geology, Library and Technical Information Services).

Age Limits: For Experimental Officers, at least 26 and under 31 on 31st December, 1953; for Assistant Experimental Officers at least 18 and under 28 on 31st December, 1953. Extension for regular service in H.M. Forces.

Candidates must have obtained, or be taking examinations during 1953 with a view to obtaining, the Higher School Certificate with mathematics or a science subject as a principal subject, or the General Certificate of Education in appropriate subjects, or the Higher National Certificate or other specified qualifications. Candidates without such qualifications may be admitted exceptionally on evidence of suitable experience. Candidates over 22 will generally be expected to have higher qualifications.

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Experimental Officers £628–£786 (men); £533–£655 (women).

Assistant Experimental Officers £274–£586 (men); £274–£490 (women).

Starting pay according to age up to 26. At 18, £274; at 26, £495 (men), £467 (women). Somewhat lower rates in the provinces.

Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S94–95/53. Completed application forms should be returned as soon as possible.

SENIOR SCIENTIFIC OFFICERS required by DIVISION OF ATOMIC ENERGY (PRODUCTION) at Sellafield, Cumberland; Salwick, near Preston; Culcheth, near Warrington, to lead research teams in theoretical and experimental work on the following topics: general physics and applied nuclear physics concerned with operation of nuclear reactors and associated processes, including health physics; physical and inorganic chemistry of metals and compounds used in atomic energy processes, including radioactive materials; extraction, purification and recovery of metals; refractory materials; physical metallurgy of radioactive metals; melting and casting of metals; X-ray crystallography of unusual metals and compounds. Qualifications: over 26 with at least 2nd class honours degree in Chemistry, Physics, or Metallurgy (or equivalent) with 3 years' post-graduate research experience. Specialised experience in one of fields mentioned desirable. Salary £781–£980. FSSU may be applicable. Good prospects. Houses within reasonable time, if married. Applications to Ministry of Supply, D.At.En.(P.), Risley, Warrington, quoting 444.

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BOOKSHELF—*continued from p. 163*

detailed examination of the period over which Crombie passes so lightly would be the first essential for any balanced assessment of what modern science really derived from the Middle Ages.

To take but one example, it is certainly true that from Robert Grosseteste (early 13th century) onwards some medievals were feeling their way towards the modern method of testing hypotheses by comparing deduced consequences with experiment and that by the 14th century one or two were actually practising what may be regarded as a close approach to this experimental method. So much Crombie describes clearly, even if he at times exaggerates. But it does not follow from this alone that when the method first appeared really clearly in Galileo it was a mere continuation of the medieval trend. After the mid-14th century the actual practice of experimenting virtually ceased. A tradition of rather abstract discussion of methodological problems carried on and it can be proved that this influenced Galileo. But the experimental practice that turns abstract methodology into scientific method had to be recreated by the moderns—and carried much further than it ever was in the best medieval period. There is a good deal of evidence to show that habitual use of experiment grew up in the late 15th and 16th centuries among superior craftsmen given new opportunities by the social conditions of the times; and that the method of Galileo arose when further social changes forced practical man and scholar closer together, and so led to a synthesis of the rather haphazard experimentation of the craft with the abstract methodology which had been transmitted through scholarly links from the great medieval period.

This view is hinted at by Crombie (p. 275), but so casually that its significance is not brought out. As against this, he suggests earlier in the book (pp. 143 ff.) that the craft-scholar synthesis really took place in the 13th century—an unfortunate attempt, as it seems to the reviewer, because the list of treatises which he cites to establish the interest shown by medieval *scholars* in technics (p. 146) is made tolerably long only by including (*a*) work by literate *craftsmen*, (*b*) works on techniques that had always been in the scholarly sphere or were associated with monastic life (medicine, calendar, bell-founding, etc.) and (*c*) even a book giving convenient snippets of craft information for use in sermons. And even if great scholarly interest in the crafts were proven, it would not be much to the point, since Crombie does not attempt to trace any real connexion between it and the methodological developments; indeed, on the contrary, he shows that the latter arose from the consideration of very abstract philosophical problems.

One could add to these criticisms a great many points at which this and that medieval achievement is greatly exaggerated in order to make it look more like its modern counterpart, or in which a progressive trend is given undue importance by isolating it from its context. But there remain the positive points with which we began. Here at last a systematic treatment of the best medieval scientific achievement is available, and any undue enthusiasm on the author's part must be compensated by a critical attitude on the part of the reader. S. LILLEY

Eastern Science by H. J. J. Winter. (*London, John Murray, 1952, 114 pp., 4s. 6d.*)

THIS book, which is published in Murray's Wisdom of the East Series, provides a brief but useful introduction to the early science of Babylon, Assyria, India and China; it then reviews some of the major scientific work done in Medieval China and Medieval India; finally there is a chapter on the Scope of Arabic Science, and a bibliography which provides a guide to some of the most relevant books in this field. The author, it may be added, is engaged on research into the history of eastern science and one hopes that this slim volume will be followed by a longer account of this subject calculated to satisfy the interest which he has aroused.

Printed and Published in Great Britain by Jarrold & Sons Ltd., Norwich. Editorial Office: 244 High Holborn W.C.1